PRODUCT ENGINEERING

JANUARY, 1952

COATED MOLYBDENUM ROD AT 2900 F.

IN THIS ISSUE — **Molybdenum • Five Bar Linkages • Stamping Design • Low Cost Shaft Couplings • Adjustable Transformer Speed Controls • Vinyl Plastisols**

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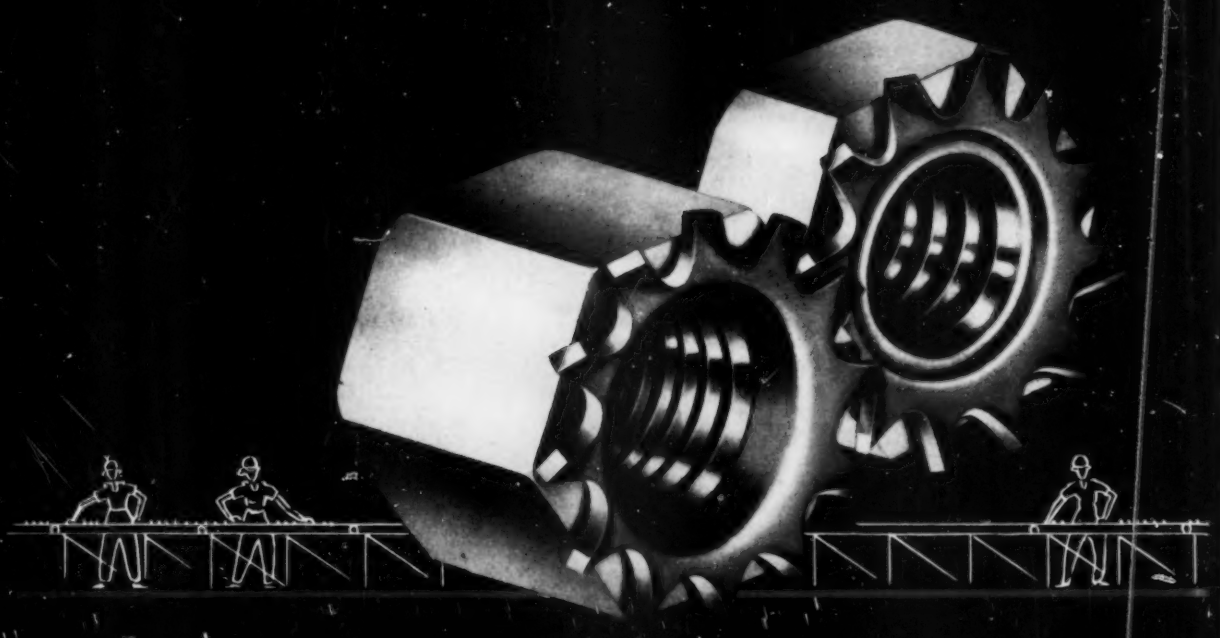

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One lock washer plus one nut used to total up to two separate assembly operations. But that was before KEPS†. Now these two separate parts are handled as a single unit because they are pre-assembled. This cuts costs, speeds production, reduces inventory problems and improves product quality.

Pre-assembling lock washer and nut was a tricky operation. The washer had to be free to rotate on the nut, and not bind on the bolt. The steel used had to have the spring demanded of a lock washer, yet it had to be easy to work to be fastened to the nut. Sharon engineers have supplied the manufacturers of KEPS† with a steel that has met all the necessary requirements.

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For information on Titanium Developments contact Mallory-Sharon Titanium Corp., Indianapolis 6

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No matter what your contact assembly needs may be, Mallory can do the *whole* job for you—from design and material selection . . . to fabrication and finishing of parts . . . to final assembly.

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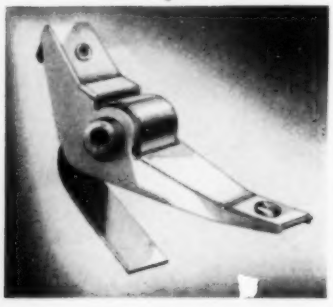

An example of Mallory contact assembly engineering is a tungsten contact assembly for an outboard motor magneto which had to withstand the impact of millions of cycles . . . resist salt water corrosion . . . maintain constant shape and uniform spring action . . . and hold the precise tolerances despite temperature and humidity changes.

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For information on Titanium Developments contact Mallory-Sharon Titanium Corp., Niles, Ohio.

Highlights

When requesting further information from companies and organizations mentioned in the items below, confusion can be avoided by referring to the issue of Product Engineering in which items appear

NONMETALLIC MATERIALS

GLASS CLOTH treated with an improved grade of silicone rubber is highly effective as motor and cable insulation. G. E's Coshocton, Ohio plant is producing the material as 36-in. widths in thickness from four to ten mils. Heat resistance, and electrical properties are excellent.

CONTINUOUS FILM of polyester resin bonded to porous materials like wood, paper and cork enhances their surface characteristics appreciably. This catalyzed Vibrin resin, made at U.S. Rubber's Naugatuck (Conn.) Chemical Division, is spead on cellophane sheet and then transferred while partially jelled to the base material for curing in a heated press. With the cellophane removed, film remains dimensionally stable, and both corrosion and abrasion resistant.

COMBINED EFFORTS of the Navy, the Air Force, and the chemical and oil industry have resulted in the first joint military specification for a synthetic lubricating oil for gas turbine engines. According to the Naval Research Laboratory, this is the first significant application of synthetic lubricants.

CEMENTS for bonding acrylic plastics have been developed by the Chemical Development Corp. of Danvers, Mass. Type CD-2 is intended for use with Plexiglas, while Types 94 and 114 are for Lucite. These monomers produce high-strength, optically-clear, bubble-free bonds, and can be used on assemblies that later are machined.

LATEST TWIST in filter-fabric construction is more twist. Current practice is half a turn per inch of yarn; new fabrics made by Equipment Development Co. of Montclair, N. J. have 25 turns. Highly twisted yarns do not pack together tightly, thereby reducing precipitation of solids in and on the fabric which is woven from all the latest synthetic fibers like Dynal.

DIELECTRIC SHEET composed basically of a Kel-F or Teflon fluorocarbon core faced with electrodeposited metal has wide application because of its versatility. Asbestos, glass fiber, mica, quartz or other inert materials can be added to the core and any of the dozen or more electrodepositable metals used as the facing. Total thickness can be varied up to about 1 1/2 in. according to engineers at U.S. Gasket Co. of Camden, New Jersey.

PLASTIC MOLDING MATERIAL consists of an Alkyd base resin with glass fiber reinforcement. Products molded of this material have excellent resistance to impact and high tensile and compressive strength, according to Plaskon, whose researchers developed it. See New Products.

METALLIC MATERIALS

SEA-WATER CORROSION of low-nickel content copper-nickel alloys can be reduced if one to two percent iron is included. Such alloys are readily worked, either hot or cold, provided they are properly heat-treated, and are suggested for condenser tubes as well as general shipboard use.

A NON-FERROUS SCRAP DRIVE is rapidly taking shape. Special industry committee has already elected permanent officers and is mobilizing for the recovery of copper, brass, bronze, aluminum and lead. Is there a Scrap Committee in your plant and is it getting in the scrap?

HIGH TENSILE STRENGTH at elevated temperatures is claimed for a magnesium-base alloy containing from one to ten percent rare earth metals, principally cerium. U.S. Patent covering the alloy is assigned to Dow Chemical Co.

TWO ALUMINUM ALLOYS have recently been developed for use in the 600-F range. Information Office of U. S. Dept. of Defense has announced a Cu-Ni-Mg-Mn-Cr-V-Ti alloy good to 600 F. and British Patent 585.610, assigned to

(continued on page 7)

IF YOUR PROBLEM
IS
BEVEL GEAR OR CURVIC COUPLING DESIGN
MANUFACTURING EQUIPMENT
PRODUCTION TIME AND COSTS
To help you . . .
THE DESIGN ENGINEER should provide us with preliminary layouts or prints of proposed bevel gear designs . . . type of drive, horsepower and speed . . . type of loading (constant, intermittent or shock) . . . type of material . . . driving member and direction of rotation.
THE PRODUCTION ENGINEER should furnish blue prints, material specifications, manufacturing tolerances . . . quantity of gears to be produced . . . number of working hours available for production.
Every day highly skilled engineers within our organization provide the answers to these problems. Backed by the company's 85 years' experience in this field, our complete engineering service is at your disposal, without obligation, to study any bevel gear or Curvic coupling design problem you may have. We will be glad to make our recommendations as to the best design, the proper equipment and the most advantageous methods for reducing production time and costs.
STRAIGHT BEVEL
SPIRAL BEVEL
ZEROL BEVEL
HYPOID GEARS
SEMI-UNIVERSAL COUPLINGS
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OVERLOAD CLUTCHES
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FOR OVER EIGHTY-FIVE YEARS
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T. F. Bradbury of Derby, England, describes a Mg-Ni-Fe-Si composition having good physicals in range from 660 to 795 Fahrenheit.

WIDESPREAD USE of ductile iron is evident by the fact that about 150 foundries in the U. S. and abroad are in production. The International Nickel Co. reports more than 75 distinctly different applications of castings ranging in weight from less an ounce to more than forty tons.

POROUS COBALT-BASE ALLOY similar to Haynes-Stellite L-605 high-temperature material is being used by Micro Metallic Corp. of Glen Cove, N.Y. in metal filters commonly made of stainless steel. Operating temperatures are therefore several hundred degrees higher than the 900 to 1,000 F range of stainless and at these temperatures tensile and corrosion resistance are comparatively better.

COMPONENTS

INTERCHANGEABLE ENGINE PARTS are close at hand. An industry advisory group for the Munitions Board has come up with a plan for standardizing high-mortality parts of gasoline powerplants used by the Army, Navy and Air Force. Group would reduce the 1,187 different moving parts of 138 different engine models to only 63 parts, and 15 bore sizes to only five.

TWO TO SIX SLIP RINGS with a separate lead for each can be built into a small assembly of 0.045-in. diameter. Ring width is 0.030 in. and barrier width 0.015 in. Silver is electroplated into grooves on a machined dielectric core by the Electro Tec Corp. of Hackensack, New Jersey.

COILED SPRINGS used in instruments and other components resist effects of moisture, weathering and chemical action when protected by a tough, thin coating that remains flexible at temperature of -70 F. Congress Fan and Electric Co. of Daytona Beach, claims units are stable to 250F.

SELENIUM RECTIFIERS are going miniature. The Plastisel assemblies made by Electronic Devices Inc. of Brooklyn, N.Y. are of standard open-plate construction with a spiral-wound phenolic wax molded case like tubular condensers. Ratings vary from 250 to 500 ma d-c for different voltages and as doubler units.

WIRING HARNESSES composed of aluminum wire joined by a new resistance method may be pressed into service by automakers. To prevent the aluminum conductors from failing in fatigue, special supports or loops may have to be used.

QUICK DISCONNECT COUPLING for electrical systems has no threads. Unit is joined or disengaged by movable fingers that grip or permit ejection of mating section, depending on the tension of a built-in coiled spring. A tug of about 20 lb opens the unit made by Wiggins Tool Co., Los Angeles.

PROCESSES

ALUMINUM SHEET is rapidly stretch-formed into contoured aircraft parts by the Demarest process at Pastushin Aviation Corp. in Los Angeles. First step is to form a cone and seam weld it by the Heliarc method. Than cone is placed in a Meehanite holder die and a rubber forming die lowered into the cone. After being locked in place, the rubber die is expanded by pumping in fluid until a pressure of 400 psi is attained. Thus, the expanding die stretches the straight-sided cone into a curved part.

CHROMIUM PLATING reduces the plastic deformation that can occur in SAE 4130 steel before fracture. Tests made at the Bureau of standards on specimens plated to nominal thicknesses of 0.0001 to 0.015 in., as well as on unplated specimens show the tensile and yield strengths decrease with increasing plate thinkness. At thickness of 0.015 in., the values are about 90 percent of those for the unplated steel.

ANY NUMBER of throws can be press forged, one at a time, in different models of crankshafts made at Compagnie des Forges et Acieries de la Marine et d'Homecourt, Saint-Chamond, France. The continuous grain process perfected by this company does away with twisting the throws.

INCONEL "W" AND "X" can be successfully welded by insert arc, metal arc and resistance welding methods. High unit pressures and slow cooling give best results. Alloys are among the most promising high temperature alloys developed by the International Nickel Company for applications up to 1,200 F. Coated Inconel 132, 132R46 or X139 electrodes are used.

(continued on page 9)

Another new development using

B. F. Goodrich Chemical Company *raw materials*

Hycar puts "the bite" on grinding costs!

Data courtesy of Austenal Laboratories, Inc., Chicago, Ill.

THIS unusual use for Hycar rubber may give you an idea—may show how Hycar can cut costs for you where fine grinding operations are involved.

The picture shows Hycar being used in the manufacture of dental restorations. The cast metal is first given a rough grind using a stone abrasive wheel. However, this operation leaves scratches on the metal surface. To remove these scratches, a Hycar bonded wheel is used.

It runs at speeds from 20,000 to 25,000 r.p.m. Naturally, there is a high heat build-up, and extreme wear and tear on the Hycar wheel. But because of Hycar's outstanding resistance to heat and abrasion, the wheel has a far longer life than types formerly used. Less dust is produced with the Hycar wheel. And, Hycar's uniformity simplifies wheel manufacturing operations, assures constant top quality.

Hycar's many advantages make it ideal for improving and developing products for many uses. Hycar rubber compounds resist heat and cold, abrasion, gas and oil, many chemicals, and more damaging factors. Demand for Hycar exceeds supply, but limited quantities available for development work. For helpful technical advice, please write Department HP-1, B. F. Goodrich Chemical Company, Rose Building, Cleveland 15, Ohio. Cable address: Goodchemco.

B. F. Goodrich Chemical Company
A Division of The B. F. Goodrich Company

Need high elasticity? Hycar has it — plus extreme temperature resistance and more advantages.

Hycar Reg. U.S. Pat. Off.
American Rubber

GEON polyvinyl materials • HYCAR American rubber • GOOD-RITE chemicals and plasticizers
HARMON organic colors

PLATING BATH for depositing aluminum apparently requires the presence of lithium aluminum hydride, aluminum chloride and the ethyl ether of the metal to insure success. The deposit has a smooth matte finish and a hardness of 37 to 97 Vickers in tests run at the Bureau of Standards.

A SPRAYED COATING of high-purity aluminum on copper-bearing aluminum alloys prevents corrosion when these materials are chosen for a given job on the basis of their high strength. The British Aluminum Co., Ltd., Salisbury House, London, finds this spray technique is useful on extrusions and castings that do not lend themselves to fabrication from Alclad sheet.

SPEEDIER DIE CASTING is the function of a nitrogen accumulator made by Hydraulic Press of Mt. Gilead, Ohio. As ram of casting machine is retracted, nitrogen is compressed into a "bottle." When ram is released, expanding gas forces hot metal into dies at 400 ft per minute.

TESTING

THE MODELS LABORATORY recently completed at the Naval Ordnance Laboratory in White Oak, Md., provides a complete study of magnetic fields, and is used primarily for tests on magnetic ship models. Results of the work are used in the protection of the Navy's fleet against magnetic field influence mines and torpedoes.

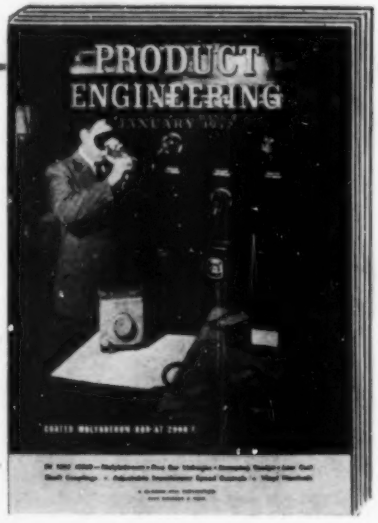
ELECTRONIC GAGE for measuring the thickness of nonconducting coatings on nonmagnetic metals has been developed at the Bureau of Standards. Instrument performs simple nondestructive test on coatings up to 0.090 in thick.

THREE-DIMENSIONAL photoelastic stress analysis technique developed at Illinois Institute of Technology determines the principal stresses at any interior point of a body. Prior to this development, only principal shears could be found. Loads are applied while a machined plastic model is heated and are not removed until after the model cools to room temperature. Stresses developed by the loads are therefore "fixed" or "frozen" into the model. Sections of the model are then studied in a polariscope.

DUPLICATING MACHINE makes exact copies of letters and other papers by a dry-process method utilizing infra-red light. The light source sends rays through a special heat-sensitive sheet to the black-and-white original copy. According to the Magna-Crest Corp. of New York City, the black type on the copy converts the rays into heat which acts on the special sheet to reproduce the image.

STANDARD TEMPERATURE of 20 C or 68 F for measurement of mechanical gages was recommended at a meeting of the International Organization for Standardization. While there is no compulsion behind these recommendations, it is expected that each of the national standard bodies making up the ISO will adopt the standards. American Standards Association is the U.S. member.

MEASURING CLEARANCES between rotating shafts and bearings is a difficult operation. A new method developed by the National Bureau of Standards for the Navy's Bureau of Ships appears to be the answer. A mutual inductance type of electrical distance-measuring element is used. The variation of the distance of the rotating shaft from two small fixed coils results in a readily measurable variation in coupling between coils.

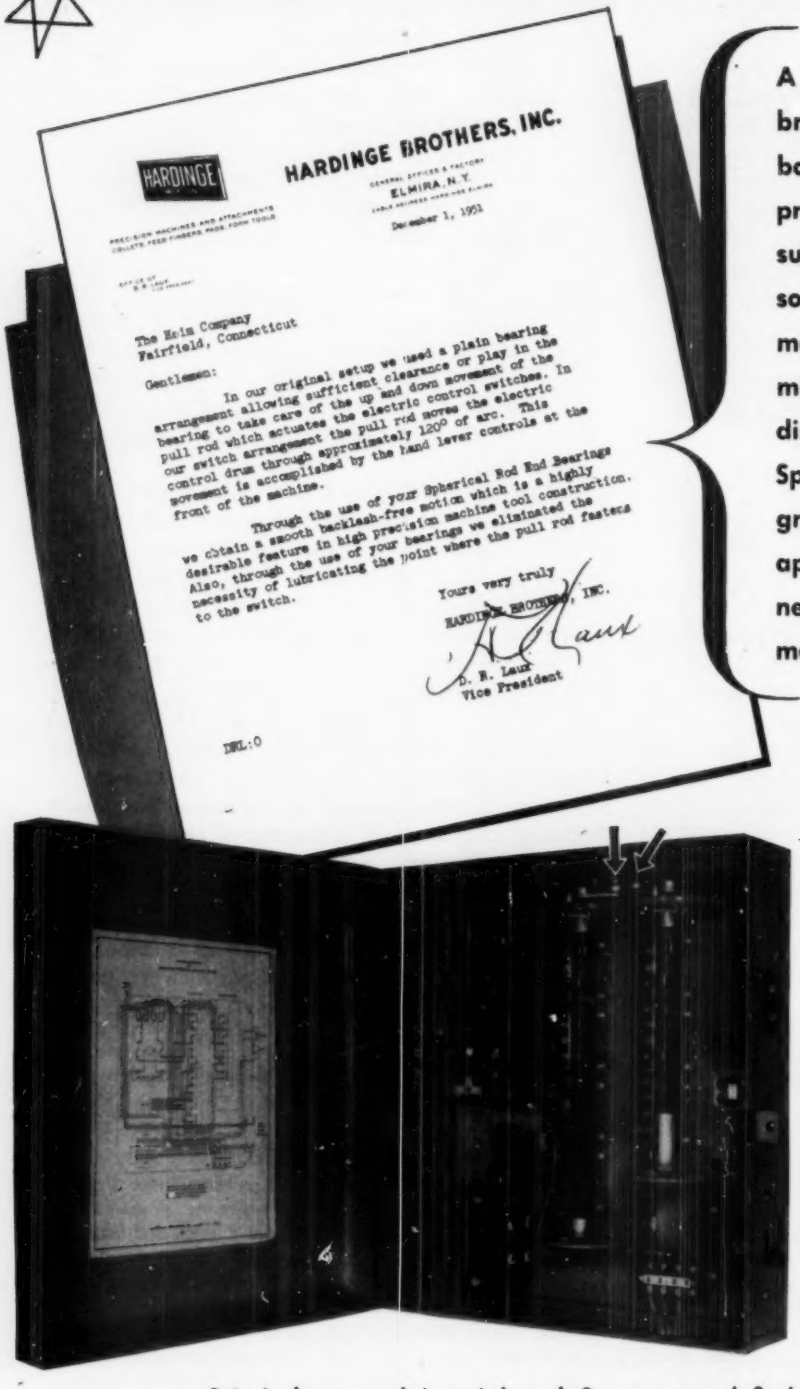


THIS MONTH'S COVER

Scientists and researchers in both government and industry have long known that molybdenum possesses excellent high temperature properties. The major problems have been (1) to develop methods of melting and fabrication that could be applied to large ingots; and (2) to develop coatings or alloys that would resist rapid oxidation at high temperatures. The subject of this month's cover is two specimens of 0.125 in. dia molybdenum rod, heated in air to a temperature of 1,600 C (2,912 F). Pure molybdenum, of course, would burn at temperatures far below this, but these specimens are protected by a siliconized coating that was developed by Fansteel Metallurgical Corporation. Shown with the optical pyrometer is Fansteel's Dr. Ralph F. Wehrmann, research chemist. For an up-to-date analysis of molybdenum's properties and potentialities, see the article starting on page 121.

HEIM *Unibal*

SPHERICAL BEARING ROD ENDS



HARDINGE BROTHERS, INC.

GENERAL OFFICES & FACTORY
ELMIRA, N.Y.

December 1, 1951

The Heim Company
Fairfield, Connecticut

Gentlemen:

In our original setup we used a plain bearing arrangement allowing sufficient clearance or play in the bearing to take care of the up and down movement of the pull rod which actuates the electric control switches. In our switch arrangement the pull rod moves the electric control drum through approximately 120° of arc. This movement is accomplished by the hand lever controls at the front of the machine.

Through the use of your Spherical Rod End Bearings we obtain a smooth backlash-free motion which is a highly desirable feature in high precision machine tool construction. Also, through the use of your bearings we eliminated the necessity of lubricating the point where the pull rod fastens to the switch.

Yours very truly
HARDINGE BROTHERS, INC.
D. R. Laur
Vice President

DRL:O

A single ball oscillating in bronze bearing inserts — bored to fit a shaft or stud, and providing a large surface supporting area. As a ball and socket operation, the universal motion of the ball corrects misalignment of the shaft in all directions. The Heim Unibal Spherical Bearing Rod End offers greater flexibility, and in many applications, eliminates the necessity for costly, precision machined components.

Write for complete catalog of Bearings and Rod Ends.

THE HEIM COMPANY

FAIRFIELD, CONNECTICUT

Standards of Worth

IN BUSINESS the most obvious and essential standard of worth is dollars profit. But any organization that has no objective other than profit will steadily disintegrate and die.

Not all plans and projects can show their worth in dollars profit. Long range research plans, support of research projects in universities, participation in industry activities, publicity, advertising and similar undertakings can never show a profit as a number on the balance sheet. But their essentiality to the growth of a successful business enterprise is generally recognized. Such expenditures are approved as a matter of course.

Over and above all these expenditures that are measured in dollars, there are others of far greater importance to a successful business. They might be termed the humanitarian efforts and actions. The time and effort they require cannot be charged off in dollars and cents. They have their birth in mental attitude and human understanding. If he possesses the proper spirit and motivating forces, any executive can put into practice the precepts that build those human relations without which no business can be a complete success.

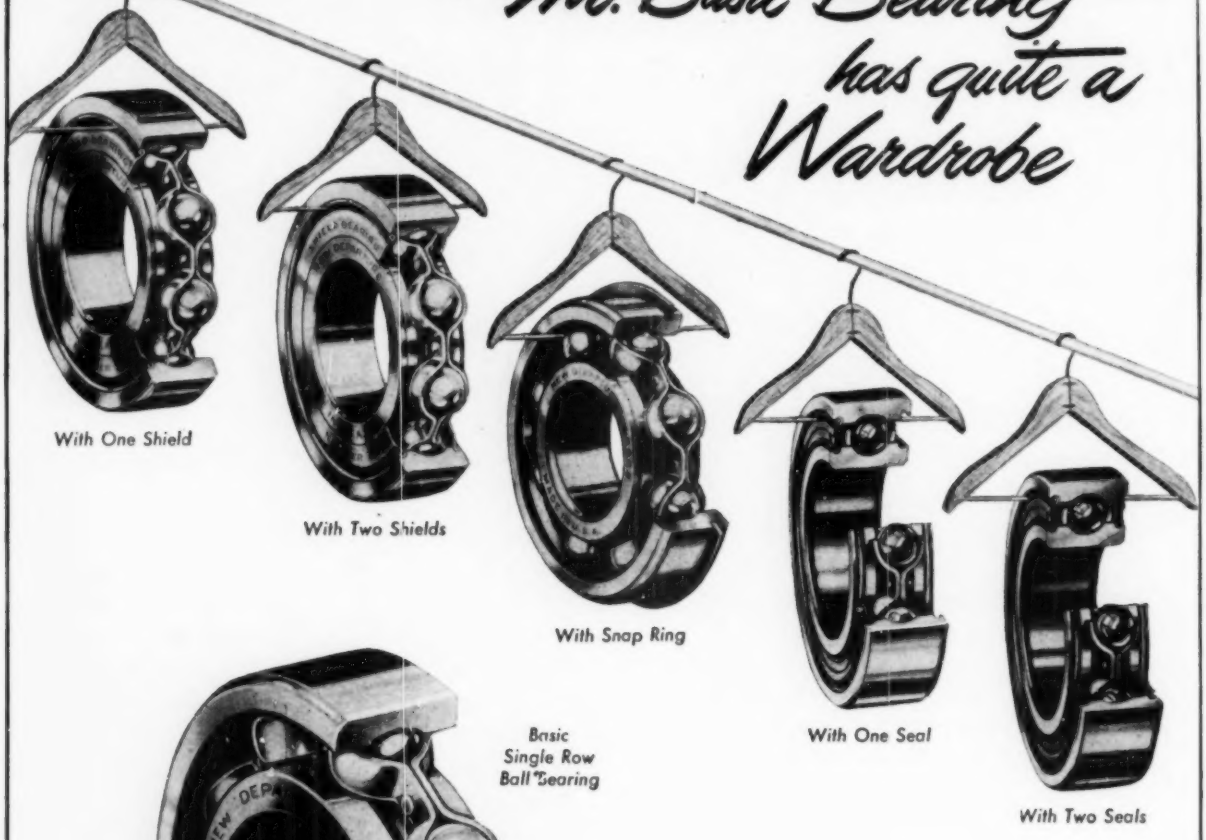
It does not require a vote of the stockholders, a resolution of the board of directors, or an order by top management for the executives and junior executives to operate according to "The Golden Rule." That is simply a matter of individual conduct and expression. Nothing more than a compassionate understanding of the troubles and limitations of their subordinates is required to censure kindly when necessary, to give unstinted praise when due, to always be fair, and to show a genuine interest in the welfare of all. Out of such treatment are built the incentives that make a job an inspiration, that put enthusiasm into effort, that foster self respect, character and happiness in the hearts of associates and employees.

When all is said and done, life has but one objective. It is happiness. You cannot purchase it, you cannot dispense it in a pay envelope. It is the cumulative dividend from investments in your treatment of others.

Let us not merely wish for a Happy New Year but also let us do something to make it so.

G. F. Zodenholt

Mr. Basic Bearing has quite a Wardrobe



With One Shield

With Two Shields

With Snap Ring

With One Seal

With Two Seals

Basic Single Row Ball Bearing

The right "dress" for every job — available as accessories to New Department's basic ball bearing.

Let us tell you more

Nothing Rolls Like a Ball...

NEW DEPARTURE
BALL BEARINGS

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONNECTICUT

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Table I—Properties of Refractory Metals

Metal	Melting point, F	Density gm/cc	Density lb/cu in.
Tungsten	6,170	19.3	0.697
Rhenium	5,740	20.0	0.720
Tantalum	5,425	16.6	0.600
Osmium	4,900	22.5	0.813
Molybdenum	4,760	10.2	0.368
Iridium	4,450	22.5	0.813
Columbium	4,380	8.57	0.310
Boron	4,200	2.3	0.083
Chromium	3,430	7.19	0.260
Sirconium	3,380	6.5	0.230
Titanium	3,272	4.5	0.164
Hafnium	3,100	11.4	0.412

Molybdenum

Our Most Promising Refractory Metal

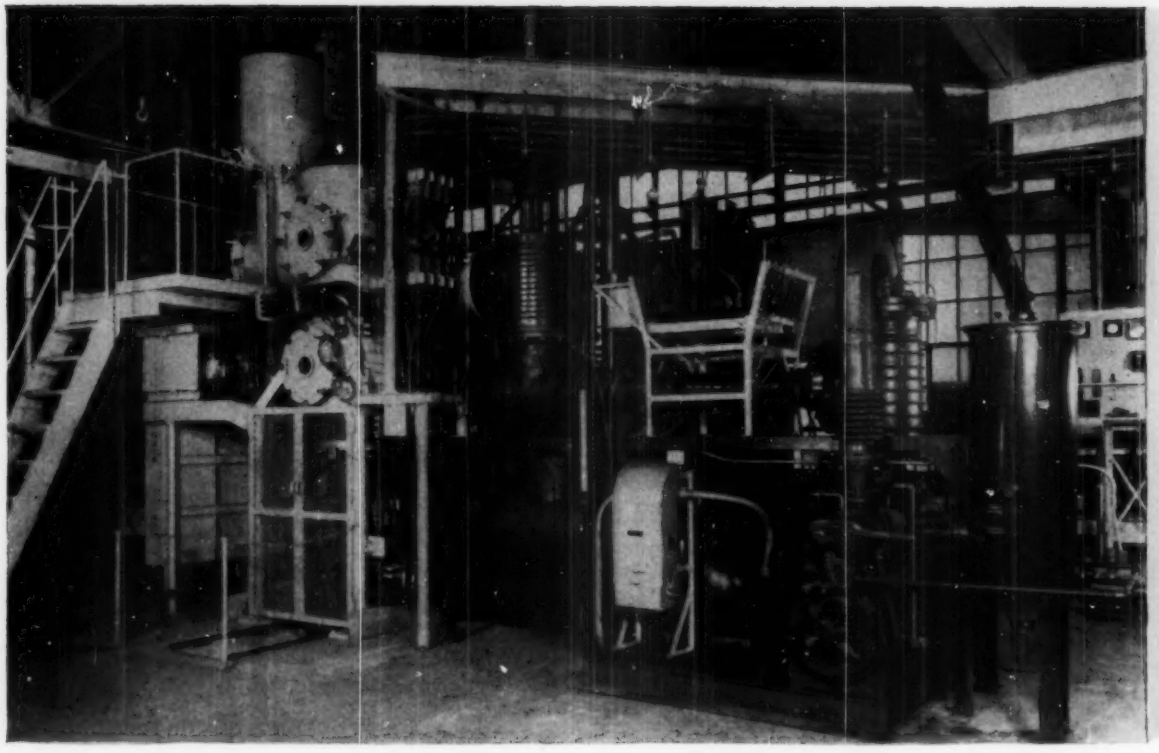
J. J. HARWOOD*
Deputy Head Metallurgy Branch
Office of Naval Research

METALLURGISTS AND DESIGNERS have selected molybdenum and its alloys as having great potential for super high temperature service. Its abundance and properties make it the most promising of the refractory metals, Table I, on which hinges the solution of future industrial and military problems involving equipment operating at temperatures in excess of 1,800 Fahrenheit.

The current search for better refractory materials stems essentially from two pressing military requirements. One is the temperature limitation of our present high temperature alloys, which do not retain useful engineering properties at temperatures greater than about 1,650 F. The second is the shortage of our major alloying elements, which has vividly demonstrated the need for less strategic high temperature metals. While leaner alloy compositions are being used successfully in gas turbines now in production, the major hope for the future of long range guided missiles and rockets and more efficient and powerful gas turbines is in the development of new alloy systems.

Molybdenum, of course, is by no means new to the metallurgical indus-

* *This paper represents only the personal views of the author and in no way reflects the official attitude of the U. S. Navy.*"



try. It has a long and distinguished record as an alloying element in steels. Its earliest usage was for filament supports in the incandescent lamp and electronic tube industries, and coiled tungsten filaments currently are wound on molybdenum mandrels. It also is used in tubes for grid windings, supports, plates, channels, caps and similar applications. The glass industry is a large consumer of molybdenum sheet, plate, bolts, and studs for electrodes involved in the melting of glass. Molybdenum also has several applications in the chemical industries.

More recently, molybdenum disulphide (M_oS_2) has been attracting attention as a lubricant. It prevents galling and seizing at bearing pressures well over 45 tons per sq in—and at either high or low velocities—which can be attributed to the unique laminar structure of the compound.

However, such specialized uses would become relatively minor, if the full structural potentialities of molybdenums were to be attained, especially in view of the abundance of ore.

The United States is the leading producer of molybdenum concentrates, mining more than 85 percent of the world's output. The chief molybdenum containing mineral is molybdenite (M_oS_2), a mineral occurring in flakes resembling graphite. Principal producers are the Climax Molybdenum Company, The Molybdenum Corporation of America, and the Kennecott Copper Corporation. Climax began active exploration of the world famous molybdenite deposits in Climax, Colorado in 1917 and since 1924 have been in constant production. In 1939, the Kennecott Copper Corporation began producing molybdenum as a by-product of their copper operations in Utah and New Mexico, which in recent years accounted for some 50 percent of our molybdenum production. The mines of the Molybdenum Corporation of America are located in Questa, New Mexico.

The reserves of molybdenum were estimated in 1945 to be in the neighborhood of 400 million tons, a more than adequate supply to meet all predictable needs. While molybdenum is currently on the critical metals list and is under allocation regulations, it is not unreasonable to expect that production capacity can be stepped up appreciably if the situation demands it.

Mining and Production Methods

In direct mining operations, molybdenite ore is recovered by the use of oil flotation processes, the final product containing approximately 90 percent M_oS_2. The concentrates are subsequently roasted to produce molybdic oxide. Molybdenum powder, which is the starting point for all current ingot consolidation processes, is made by the hydrogen reduction of molybdenum trioxide or ammonium molybdate. The above chemical operations and reduction processes must be carefully controlled to produce powder of desired purity, particle size and particle size distribution.

Because of the adverse effects of impurities on the ductility and workability of molybdenum, and because of the high melting point of the metal, all molybdenum ingots and shapes have been produced by powder metallurgy techniques in the past. Industrial concerns such as Fansteel Metallurgical Corporation, General Electric Company, and Westinghouse Electric Corporation have, for many years, made ingots by such methods.

The molybdenum powder is generally placed in steel dies and compacted into ingots under high pressures. These "green" brittle bars are then densified and strengthened by electrical resistance sintering. Each end of the bar is gripped in a water cooled electrode, and a heavy current is passed through it. The sintering temperature is about 2,340 C. This operation is conducted in an atmosphere of pure hydrogen to prevent oxidation or con-

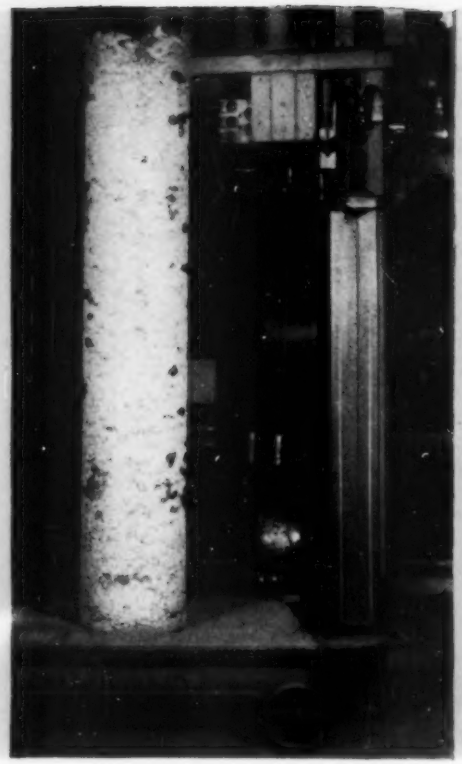


Fig. 1—Arc casting equipment capable of producing one-ton molybdenum ingots. Five years ago, the maximum size ingot that could be produced by this process was about 25 pounds. Improvements in fabrication and application techniques have kept pace.

Fig. 2—One-half ton cast ingot produced by the Climax Molybdenum Company by arc melting. Such ingots are melted directly from metal powder. The molten metal is deoxidized to insure forgeability.

tamination. The bars are then rolled into plate or sheet, swaged into rod, drawn into wire or forged to special shapes.

The size and shapes of bars made by the above method is obviously limited by the pressures that would be required for pressing large ingots and the current requirements for insuring complete soundness after sintering. However, today it is not uncommon to produce sintered molybdenum shapes measuring up to 6 in. square, 4 ft long and weighing over 400 lb.

Another production method is more closely allied with conventional powder metallurgy techniques. It consists of pressing powder under high hydrostatic pressures, and then sintering the green ingot in furnaces at temperatures of 1,500–1,700 C. Westinghouse is now producing molybdenum by this method, using water-saturated hydrogen furnace atmospheres.

Although the average ingot weight by this process is about 50 pounds, rectangular pieces 5 ft long and weighing 700 lb, or rounds 5 ft long weighing as much as 1,000 lb can be produced.

Cast molybdenum ingots also are being produced. Casting techniques and equipment have been vastly improved during the past five years with a corresponding increase in ingot weight from 25 to 1,000 lb. Six inch diameter ingots weighing about 200 lb have been produced regularly by the Climax Molybdenum Company. Recently developed equipment with capacity for arc casting a one ton ingot is shown in Fig. 1. One-half ton cast ingot is shown in Fig. 2.

The arc-cast process makes molybdenum castings "direct" from molybdenum powder. The powder is extruded into a continuous electrode which is further strengthened by partial sintering by electrical resistance heating. The end of the electrode is melted in the arc and the liquid metal is collected in a water cooled copper mold that serves as both the melting chamber and casting mold. The alternating-current arc is sustained between the consumable molybdenum electrode and the pool of liquid metal. The entire operation is done under high vacuum.

To insure forgeability, the molten molybdenum is deoxided by additions of carbon to the powder and the resultant carbon monoxide is pumped off during the melting operations. The oxygen content of the ingot must be maintained below 0.003 percent to prevent oxide precipitation at grain boundaries and subsequent brittleness. It is interesting to note that fractographic techniques have been employed to detect the presence of these nonmetallic constituents and to provide prior indication of the forgeability characteristics of the ingot.

Another type of equipment developed by Climax makes use of preformed bar electrodes either made by the powder metallurgy process or rolled from arc-cast ingots. In this latter unit, vacuum or inert atmospheres may be used.

The price of molybdenum powder ranges between \$4-\$6 per lb, with the cost of an arc cast ingot running about \$10 per lb. Molybdenum bars cost about \$13 per lb while the price for plate ranges from \$20–\$45 per lb, depending upon plate thickness. The prices vary somewhat among the fabricating producers.

TABLE II—Physical Properties

Melting point	4,750 F	(2,622 C ±10 C)
Boiling point	10,270 F	(5,690 C)
Modulus of elasticity	46–50 x 10^6 psi	(at 70 F)
Modulus of rigidity	17 x 10^6 psi	(at 75 F)
	16.1 x 106 psi	(at 1,100 F)
Poisson's ratio	0.307	(at 80 F)
	0.321	(at 1,600 F)
Density	10.2 g/cc	(0.368 lbs/cu in.)
Specific heat	6.24 cal/gm atom/°C	(at 20 C)
Linear coefficient of thermal expansion	5.45 x 10^{-6} per deg C	(at 20 C)
	3.0 x 10^{-6} per deg F	(at 70 F)
Thermal conductivity	0.349 cal/sec/cm/deg C	(at 20 C)
Electrical resistivity	5.17 microhm-cm	(at 0 C)
Temperature coefficient of electrical resistivity (20—100C)	0.0047 per deg C	
Heat of fusion	About 50 cal/g	
Heat of vaporization	About 1,340 cal/g	
Atomic No.	42	
Atomic weight	95.95	
Crystal structure	Body centered cubic	
Electron work function	4.20 ev	
Magnetic susceptibility	+53.3 x 10-6 gm atom	

Table III—Room Temperature Properties of Molybdenum*

Method of Production	Tensile strength, psi	Yield strength, psi	Elongation % in 2 in.	Hardness
POWER METALLURGY PROCESS				
Rod 0.050 in. as worked	120,000	70–90 percent of Tensile strength	5	100 Rb
0.050 in. annealed	90,000		15	95 Rb
Wire 0.010 in. as worked	170,000		1	24 Rc
0.010 in. annealed	125,000		15	100 Rb
Sheet 0.020 in. as worked	165,000		1	26 Rc
0.020 in. as annealed	125,000		7	95 Rb
ARC CAST PROCESS				
Sheet 0.050 in. annealed	105–125,000	101–115,000	13–22	
0.020 in. annealed	105–125,000	100–123,000	8–15	
0.013 in. annealed	108–125,000	102–120,000	8–14	
Sheet 0.020 in. cold rolled	154,000	151,000	5	
0.030 in. hot rolled	108,000	102,000	12	

* Values are average. Properties vary with fabrication history, directionality, strain rate, metallurgical structure, and other factors.

Table IV—Directionality Effects on Room Temperature Tensile Properties

Material*	Relation to final rolling direction	Tensile strength, psi	Yield strength, psi	Elongation percent in 2 in.
Straight rolled	Parallel	103,600	109,000	11
	Transverse	114,900	117,300	13
Cross rolled	Parallel	108,900	114,100	14
	Transverse	123,500	125,100	12

* 0.20 in. sheet annealed at 1,800 F.

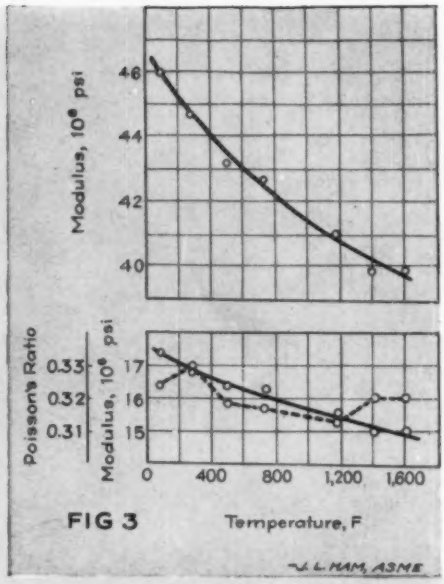


Fig. 3—The high modulus of elasticity of molybdenum makes it especially suitable for applications requiring high rigidity. Top curve shows Young's modulus, bottom curve (solid line) modulus of rigidity.

Physical and Mechanical Properties

In addition to desirable high temperature properties, molybdenum possesses an attractive set of physical and electrical characteristics. Its melting point is exceeded by only two engineering metals, tungsten and tantalum, and by few elements in general. As a matter of fact, its melting point is approximately 1,800 F higher than currently used high temperature alloys.

Its specific heat and coefficient of thermal expansion are about half of that of steel, Table II, and its thermal conductivity is about three times greater. These thermal characteristics provide molybdenum with advantageous heat-transfer and thermal shock properties, especially useful where nonuniform temperature conditions and temperature cycling effects are involved. Dimensional stability is consequently greater and thermal stress problems are lessened. The electrical conductivity of molybdenum is about ⅓ that of copper or silver, exceeded only, in this respect, by aluminum, gold and magnesium.

Another characteristic of molybdenum is its high modulus of elasticity which makes it favorable for applications where high rigidity requirements prevail. This modulus is not seriously affected by elevated temperatures, as shown in Fig. 3, but varies with sheet directionality and cold work.

Representative room temperature tensile properties for molybdenum are listed in Table III. Considerable variation exists in the published data on the strength properties of molybdenum, and it is clear that the mechanical properties are responsive to small changes in fabrication history. Some indication of the variation in properties with sheet direction is shown in Table IV. While unalloyed molybdenum possesses desirable tensile properties whether made from arc-cast ingots or powder metallurgy ingots, sheets cross-rolled from the latter material are more sensitive to 45 deg brittle cracking when bent cold.

The effects of annealing treatments on the room temperature properties of arc-cast molybdenum materials are shown in Table V. Below the tem-

Table V—Effects of Annealing on Properties of Arc Cast Molybdenum

Annealing Temperature, F	Yield point, psi	Tensile strength, psi	Elongation percent in in.	Reduction of Area	Hardness, VPN
COLD ROLLED SHEET, 0.20 IN.					
As Rolled	151,800	154,200	5		
1,600	126,500	131,500	12		
1,700	121,500	124,500	10		
1,800	111,000	117,300	13		
1,900	98,000	105,500	17		
2,000	75,400	88,900	29		
2,100	73,100	91,300	28		
2,200	75,500	90,600	26		
2,300	81,500	88,400	26		
2,400	75,400	78,800	39		
(½ IN. DIA)					
Hot Rolled	99,800	100,100	32	60.9	255
1,700		91,700	39	59.2	
1,900	84,700	90,800	41	65.7	
2,100	54,100	73,100	53	64.2	187
2,200	50,100	73,600	55	55.6	187

perature range of 1,700 to 1,900 F, stress relief occurs with no appreciable drop in properties; above this range, recrystallization takes place with typical softening reactions. Severely worked metal may recrystallize as low as 1,650 F, but recrystallization generally begins about 1,900 F. Pure arc-cast molybdenum has a hardness of about 170–190 VPN which can be raised to 300 VPN by severe cold work. Recrystallization drops the hardness to about the level of as-cast metal.

The ductility and reduction of area values obtained from tensile specimens, provide no indications of any abnormal ductility characteristics. Yet, in the present stage of development of molybdenum it cannot be considered as a completely ductile metal for comprehensive structural usage. Under many conditions molybdenum behaves in a brittle manner. It is quite "strain rate" and "notch" sensitive and when subjected to complex stresses or impact, such as in gas turbine blading, for example, will exhibit poor toughness characteristics at room and moderate temperature conditions.

When as cast, or in an equiaxed recrystallized condition, metal exhibits poor room temperature impact properties and fails in a brittle manner under impact conditions. This anomalous behavior of recrystallized material, which ordinarily would have superior ductility characteristics over wrought material, is the subject of considerable research. Under Office of Naval Research contract, Battelle Memorial Institute and Johns Hopkins University are investigating the factors responsible for this phenomenon. At present, it is believed that embrittlement is caused by impurities. Intergranular brittleness has been shown to be related to the purity of the metal, and transgranular brittleness may also be due to impurities. Recent work at Battelle has shown that high purity molybdenum has greater ductility than commercial grades. Under some conditions in which commercial molybdenum has zero ductility, high purity molybdenum in the as cast condition is ductile. Single crystals of commercial purity molybdenum, grown at Johns Hopkins are ductile in tensile tests, but are still strain-rate sensitive.

Wrought material exhibits greater ductility than recrystallized material, and the experience of the molybdenum industry in working either powder metallurgy, or arc-cast molybdenum gave rise to the conclusion that a fibrous structure was essential for maximum ductility. However, more recent findings indicate that impurity effects are the more important factors.

Similar to steels and other body centered cubic metals, molybdenum displays a transition temperature effect; it undergoes a transition from ductile to brittle fracture as the temperature of deformation is lowered. The transition temperature is a function of the state of stress and strain rate. Complicated stress systems (triaxial stresses) and high rates of loading raise the temperature at which brittle fracture occurs. With the standard notched bar Charpy test, molybdenum is brittle at room temperature. The energy absorption-temperature curves for molybdenum are shown in Fig. 4 for a variety of test specimens.

While the temperature at which commercial molybdenum becomes ductile varies with the stress systems of the specimens used, the range over which the fracture transition occurs is sharp, sometimes occurring in a temperature range of 5 F. The lowest V-notch Charpy transition temperature was obtained with as-rolled specimens. Recrystallization treatments raise the transition temperatures to high values. These high transition temperatures exhibited by commercial molybdenum are indicative of potential difficulties that might arise during the manufacture and assembly of molybdenum components. An important phase of the research and development programs now underway is the study of the factors responsible for these high transition temperatures, with the ultimate objective of lowering the transition region whereby the metal can be satisfactorily employed for the stress and strain conditions of normal engineering usage.

The effect of strain rate on the tensile properties of molybdenum has recently been determined, Fig. 5. With a variation in strain rate from 0.018 x 10^{-3} to 1.38 x 10^{-3} an increase in the tensile strength and yield point of 11 and 12 percent respectively occurred with a corresponding decrease in elongation and reduction of area of 47.2 and 16.5 percent respectively. The results indicated that the following relation expressing the effect of strain rate on yield strength holds:

$$\sigma = K(\epsilon)^n$$

where σ is the stress, $\dot{\epsilon}$ the strain rate, and K and n are material constants.

While it is apparent that the room temperature mechanical and physical properties of molybdenum are outstanding, a number of important obstacles must be overcome before the metal and its alloys can be widely used for certain structural and engineering purposes, particularly at high temperatures.

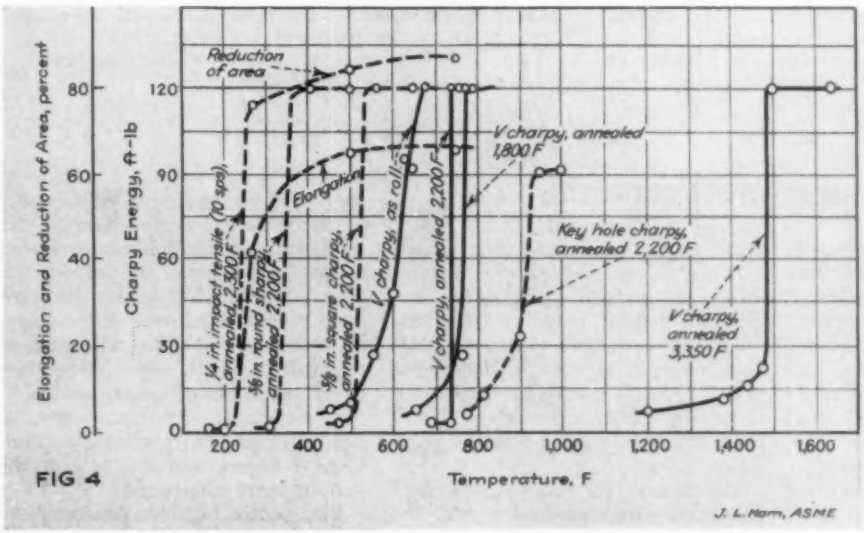


Fig. 4—Molybdenum is relatively brittle at room temperatures. The transition from this brittle to a ductile state occurs over a short temperature range as temperature is increased, but the temperature of transition varies with the stress system of the specimen. High values may give difficulty in fabrication and assembly operations.

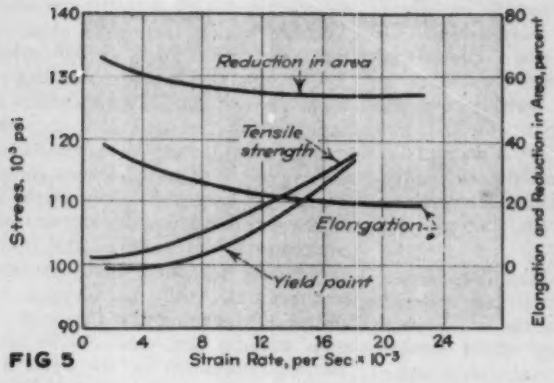


FIG 5

Fig. 5—Effect of strain rate on tensile properties. On a log plot of strain rate, a straight line relationship ensues.

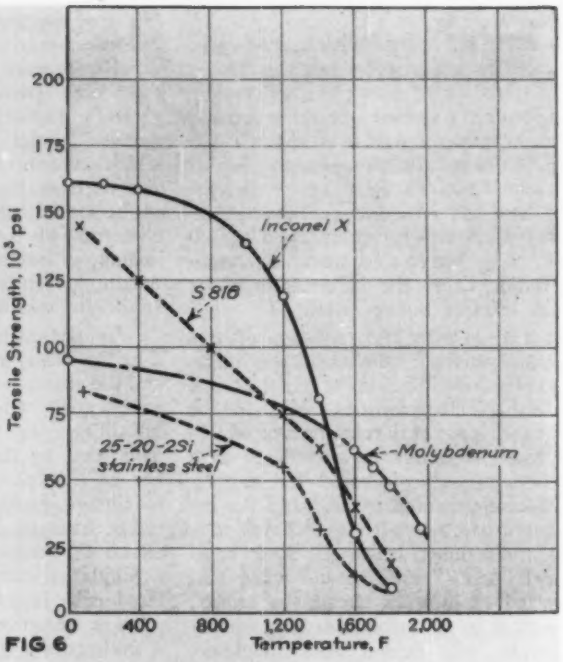


FIG 6

Fig. 6—How the tensile strength of molybdenum compares with other heat resistant metals at elevated temperatures. Above about 1,400 F it is superior to most alloys, and above 1,800 F it still has appreciable strength.

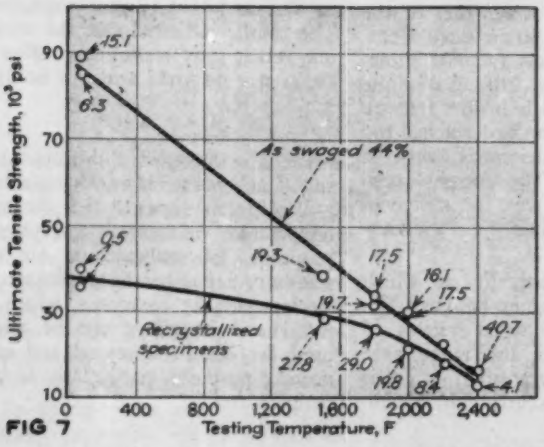


FIG 7

Fig. 7—Effect of temperature on swaged and recrystallized specimens of modybdenum produced by the powder metallurgy process. Test specimen was ¼ in. diameter. Figures on curves indicate elongation in 1¼ inches.

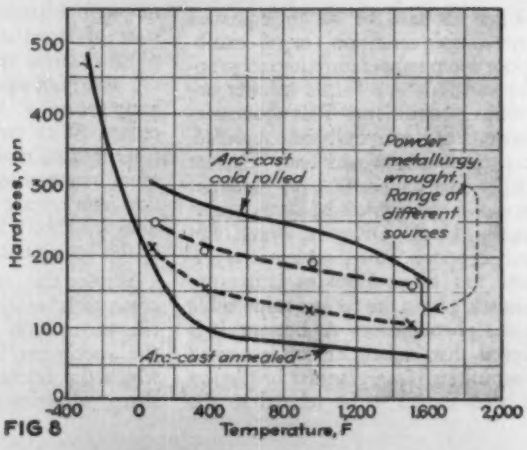


FIG 8

Fig. 8—Hot hardness curves for molybdenum produced by powder metallurgy techniques and by arc-casting. The behavior patterns in all material are similar, even though values differ.

High Temperature Properties

The known high temperature strength properties of molybdenum have been responsible for the extensive interest in this metal for applications such as turbine blades, rocket nozzles, combustion chambers, and similar applications. Information available several years ago, indicated that above about 1,600 F, the creep and stress-rupture properties of commercially pure molybdenum were superior to those of any of our high temperature alloys, which are either cobalt, iron or nickel base alloys. In Fig. 6 is a comparison of the high temperature tensile properties of molybdenum with some of our super alloys; whereas the strength characteristics of presently used high temperature alloys deteriorate rapidly above 1,650 F. moly still retains useful strength properties.

Of course, the high temperature properties vary considerably with the source of molybdenum powder and purity of the powder, method of consolidation, fabrication history and other factors. Comparison of properties is apt to be misleading unless the specimens have received equivalent amounts of work or are in comparable states of recrystallization. A recent comparison of the properties of arc cast and powder metallurgy specimens revealed equivalent properties when the metallurgical history and structure of the samples were equivalent.

Data on the high temperature prop-

erties of powder-metallurgy molybdenum has been published by the National Advisory Committee for Aeronautics and by Battelle Memorial Institute. The effects of temperatures on the tensile strength and hardness of molybdenum are shown in Figs. 7 and 8. Note that the recrystallized specimens had lower strength values than the swaged specimens at all temperatures. Only at temperatures above 2,000 F do the values approach each other, presumably due to recrystallization of the wrought material at these elevated operating conditions.

Of more importance to the design engineer concerned with turbine blade development are the stress-rupture and creep properties of molybdenum. These data provide a more reliable index of the long-time high temperature behavior than hot hardness or short time elevated temperature tensile tests. Creep-rupture data are still preliminary. Nevertheless, the results indicate that the creep properties of commercially pure molybdenum at 1,800 F and above are superior to commercial high temperature alloys. Creep-rupture data for molybdenum within the temperature range of 1,600-1,800 F inclusive are shown in Figs. 9 and 10 in comparison with several commercial alloys. Part of the Navy program at Battelle is concerned with the measurement of the creep-rupture and other high temperature properties and the study of the factors affecting them. Tests conducted at these high temperatures require several special techniques, and the specimens must be protected against oxidation.

Oxidation and Corrosion Resistance

When molybdenum is heated in air, a trioxide molybdenum, M_o0_3, is formed on the surface. The oxide has a low melting point—1,460 F—and vaporizes below the melting point even in atmospheres containing small amounts of oxygen. At 1,800 F, for example, in slow flowing air, molybdenum oxidizes at the rate of 0.02 to 0.05 in. per hr. Obviously such a metal weight loss would make the use of the molybdenum under oxidizing conditions impossible.

Various methods of overcoming the poor oxidation characteristics and providing adequate surface protection are being investigated, and some are moderately successful. However, no method has yet been developed that provides completely reliable oxidation protection, particularly above 1,800 F, and at the same time leaves the room temperature ductility unchanged.

Most of the processes can be classified under the general types of either "diffusion" coatings or ceramic coatings. The former consist of covering the surface, by electroplating, vapor phase deposition, or cladding, with a metal that has better resistance to oxidation than molybdenum or that forms an oxidation resistant alloy with it. These coatings eventually fail because of the diffusion of molybdenum into the protective layer. Above a certain surface concentration of molybdenum, rapid oxidation then occurs. Coatings of aluminum, chromium and nickel have provided some degree of protection, but the most promising protection has been displayed by coatings of molybdenum disilicide. Life tests of over 5,000 hr. at 1,800 F, and over 300 hr. at 3,100 F have been obtained with coatings 2 mils thick. The coatings have also shown good service under load and when subject to thermal cycling. The coating melts at about 3,300 F, thus limiting the useful temperature range, and methods still need to be developed for deposition in thicker layers and in a more feasible and economical manner. Vapor deposi-

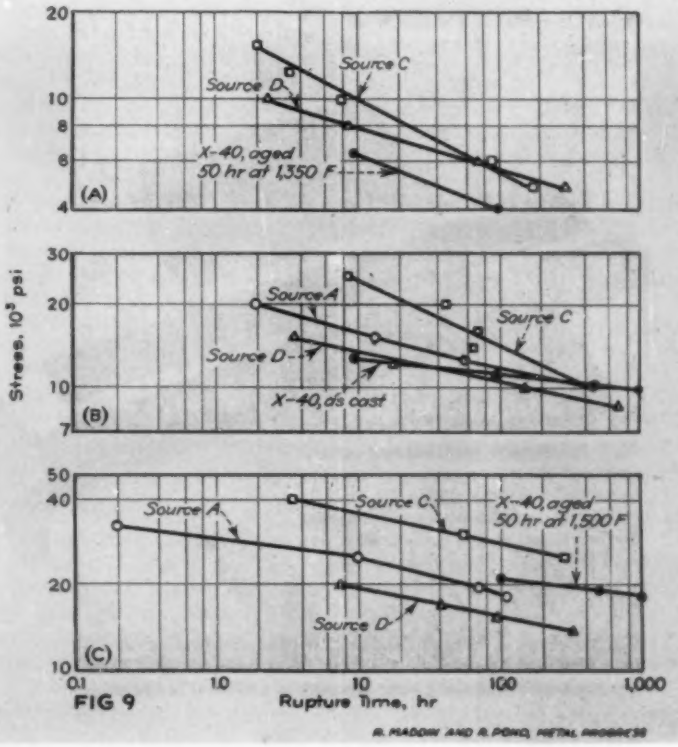


FIG 9

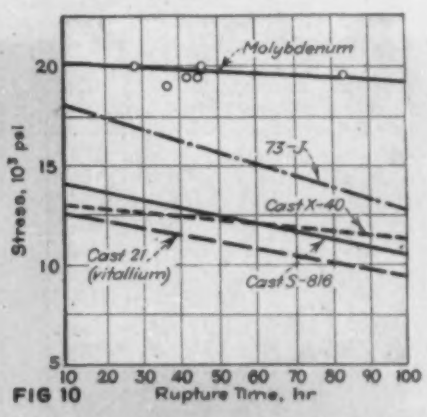


FIG 10

LOAR, DYKE, AND BEAR METAL PROGRESS

Fig. 9—Creep-rupture properties of recrystallized molybdenum at (A) 2,000 F (B) 1,80 F and (C) 1,600 F. Alloy X-40 is a cobalt base alloy produced by Haynes Stellite Company.

Fig. 10—Comparison of stress rupture life of molybdenum with commonly used high temperature alloys. Data was obtained on ½ in. wrought molybdenum bars. All tests were at 1,800 F.

tion techniques are currently being used.

The Fansteel Metallurgical Corporation has recently announced the availability of siliconized molybdenum bar, rod, wire, tubing and fabricated parts. Electric resistance heating elements, nozzles and jets for gas and oil burners, thermocouple tubes and jet engine parts are promising applications for these coatings. Unlike ceramic coatings, the siliconized coating is a conductor, so that electrical contact can be made through the coating.

Some ceramic coatings have also shown excellent promise. Coatings developed by the Bureau of Standards showed no deterioration when exposed in air at 1,650 F for 70 hr. Unprotected 0.040 sheet molybdenum lost half its original thickness after ½ hour at the same temperature. Firing temperatures of ceramic coatings are also above the recrystallization temperature of molybdenum so they suffer from the same disadvantages discussed previously. Undoubtedly, both diffusion and ceramic coatings provide adequate protection for usage not involving severe shock or impact loading. Both types, however, must be nonporous, gas-tight, and free from imperfections to insure reliable protection.

Cladding of molybdenum with nickel or Inconel has been shown to be feasible for some high temperature applications. However, the relatively low melting points of the cladding materials, edge effects, and temperature limitations will limit the use of such methods.

The development of oxidation resistant alloys is also being investigated, although this approach does not appear to offer much promise, at least at this stage of the alloy picture. Alloys have been developed with significantly superior oxidation resistance as compared to pure molybdenum (but still excessive for engineering usage). However, the amounts of alloying additions required to provide this improved protection are sufficient to make the alloys completely unworkable.

It has been reported that molybdenum can be deposited as an adherent coating upon base metals by low temperature decomposition of molybdenum carbonyl vapor (pyrolitic plating). While the process has not been completely perfected as yet, it has been applied on a small scale to such components of electrical appliances as copper magnetron anodes, magnetron rings, etc. Thin coats of metallic molybdenum can also be electrodeposited from aqueous solutions of molybdic acids containing high concentrations of salts. Formates, propionates, fluorides and phosphates have been successfully used. Copper, nickel, and iron cathodes have been coated with molybdenum with a plate thickness of approximately 0.003 mm. Cobalt, iron and nickel alloys of molybdenum can be codeposited from these baths and from aqueous citrate baths.

Fabrication and Processing

As indicated earlier, the forging and rolling of massive molybdenum have advanced to the stage where equipment size limitations represent the major problem in working large pieces. Powder metallurgy ingots are usually broken down by rolling whereas cast ingots are either forged initially or rolled. The cast ingot must be turned down to remove rough surface layers prior to working. Working temperatures are in the neighborhood of 2,400 F.

For successful forging of molybdenum the oxygen content must be maintained below a certain minimum. Carbon is presently used as a deoxidizer in the arc-cast process, but carbon in excess of 0.06 per cent also results in non-forgeability due to carbide formation. Research is currently underway on the investigation of other deoxidizers that might be more efficient and powerful and several of these exhibit promise.

Forged or rolled billets can be subsequently rolled into rods, bars, rounds, sheet, strip or extruded into tubing.

Some recent work has indicated that

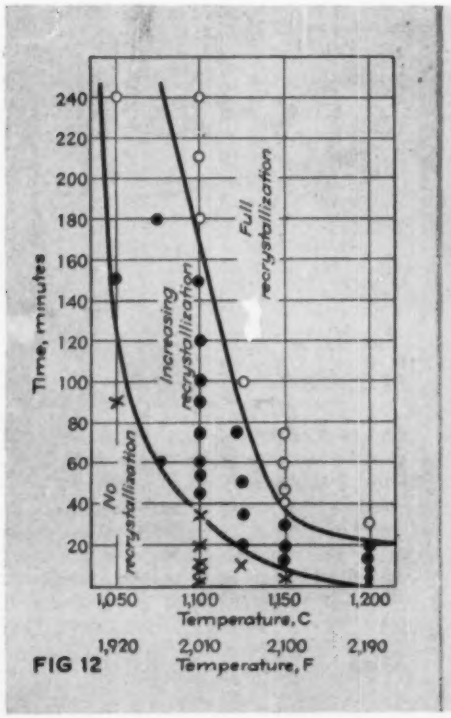
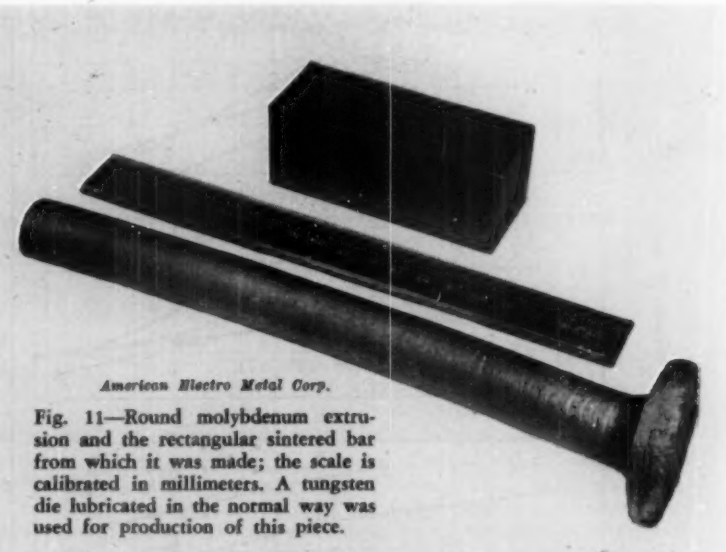


FIG 12

Fig. 12—Typical recrystallization time-temperature data for 0.02 in. rolled molybdenum sheet. Below 1,600 F no recrystallization was noticeable after long time exposure of 134 hr at temperature.



American Electro Metal Corp.

Fig. 11—Round molybdenum extrusion and the rectangular sintered bar from which it was made; the scale is calibrated in millimeters. A tungsten die lubricated in the normal way was used for production of this piece.

molybdenum ingots can be directly extruded into tubing by the recently developed Ugine-Sejournet process which employs special lubrication techniques. Using materials, such as glass, which have wide melting ranges and are viscous at the extrusion temperature as lubricants between the die and the work piece, alloys normally difficult to roll or forge have been successfully extruded. Uniform working of the ingot is obtained, and it is anticipated that greater strength and toughness characteristics will result.

There is good reason to believe that some of the higher strength molybdenum alloys which are now under development and which are difficult to forge can also be successfully extruded by this process. Several American companies are licensed under this process and plant facilities are now being established in this country. As shown in Fig. 11, a fair degree of success also has been obtained with conventional extrusion of molybdenum billets.

As a result of the high transition temperature of molybdenum, forming operations as shearing, bending, crimping, drawing, upsetting and spinning should be performed at elevated temperatures to minimize the occurrence of brittle cracks, particularly for heavier stock. For those forming operations in which the applied stresses are of a complex nature, rates of deformation should not be high. Many forming operations which result in cracks when conducted at room temperature are entirely feasible and readily performed at temperatures of about 400 F. The initial drop in hardness resulting from moderate temperature treatment as shown in Fig. 8, helps to explain this increased workability.

However, sheet can be cold rolled to a thickness of 0.001 in at room temperature. "Know-how" has so increased that cross-rolled molybdenum sheet under 0.020 in. can be bent 180 deg. in any direction around a 1-T bend radius. Between 0.020 and 0.040 in. sheet thickness, working should take place within the temperature range of 200 to 325 F, and for heavier stock 900 to 1,000 F temperatures should be employed.

Similar recommendations also hold for blanking, punching or shearing. It has been reported that such operations require sharp dies to avoid lamination and cracking of the sheet, and that it is good practice to heat the dies with infra-red lamps.

In drawing molybdenum, the number of draws should be held to a minimum to avoid the possibility of cracking; and if possible, the part should be designed to be drawn in one operation. Materials such as aluminum bronze with low coefficients of friction are recommended die materials. Steel dies well lubricated with light oil have also been used.

Molybdenum can be spun into many shapes using conventional techniques and temperatures of from 200 to 400 F. As in other forming processes, the heavier the sheet and the greater the reduction, the higher is the temperature required for successful forming. Aluminum bronze tools or other materials with low coefficients of friction are also employed for spinning.

Cross-rolled sheet usually is specified for drawing, spinning and forming operations to insure that the sheet have sufficient ductility for forming in all directions.

Seamless molybdenum tubing is available in dimensions from $\frac{1}{2}$ in. OD down in several wall thicknesses. Such tubing is extruded and drawn to size.

If the forming operations require intermediate annealing treatments, the time-temperature conditions should be selected to prevent recrystallization and thus avoid embrittlement of the sheet. Stress relieving can generally be accomplished below 1,900 F and one fabricator recommends an annealing temperature of 1,830 F for not more than 3 minutes. A typical recrystallization time-temperature curve for 0.002 in. rolled molybdenum sheet is shown in Fig. 12. Below 1,600 F no recrystallization was noticeable even after 134 hr. while at about 1,900 F recrystallization started. after 2 hours.

With respect to machining operations, molybdenum can be shaped, sawed, turned, reamed, drilled and bored. Molybdenum machines with a crumbling chip, and tungsten carbide tools are recommended, although it is possible to use high-speed steel tools. The best machining properties occur with worked molybdenum when a uniform fine fibrous structure exists. The depth of cut should always be greater than 0.005 in. to minimize tool wear. To prevent chipping, the tools must be

Table VI—Chemical Properties of Molybdenum*

Corrosive Medium	Temperature, C	Reaction with molybdenum
H_2SO_4, dilute	20	Attacked very slightly
H_2SO_4, dilute	100	Attacked slowly
H_2SO_4, conc.	20	Attacked slowly
H_2SO_4, conc.	110	Attacked slowly
HCl, conc.	20	Attacked very slightly
HCl, conc.	100	Attacked slightly
HCl, dilute	110	Attacked slowly
HNO_3, conc.	20	Forms protective film
HNO_3, 25 percent	20	Attacked rapidly
HNO_3, conc.	100	Attacked rapidly
Aqua Regia	100	Attacked rapidly
HF	20	Attacked slightly
HF	100	Attacked slightly
HF + HNO_3	20	Attacked rapidly
H_3PO_4, 10 percent	20	Attacked
H_3PO_4, 10 percent	100	Attacked rapidly
Chlorine, dry	....	Attack begins at about 250 C
Bromine, dry	....	Attack begins at about 250 C
Iodine, dry	800	Not attacked
Fluorine, dry	20	Attacked
Air	20	Tarnished in moist air
Air	....	Oxidation begins at 300 C
Hydrogen	....	Not attacked
Oxygen, dry	....	Ignites at 500 C, oxidations begin at 300 C
Nitrogen	....	Nitriding begins 1,500 C
CO	....	Carburizing begins 1,400 C
CO_2	....	Oxidation begins 1,200 C
Water	20	Attacked very slightly
Steam	700	Attacked
H_2S	20	Not attacked
H_2S	1200	Attacked
NH_4OH solution	20	Attacked very slightly
NaOH, 10 percent solution	100	Not attacked
NaOH	Fused	Attacked rapidly
Sulphur, dry	....	Attacked at red heat
Carbon	....	Carburizing begins at 1,100 C

* Fansteel Metallurgical Corporation

very rigidly supported. Tool angles and rakes similar to those used for cast iron work are satisfactory.

For turning and milling, sulfur-base cutting oil lubricants have proven satisfactory. Sulfur-base cutting oils are also recommended for drilling, tapping or threading. High speed steel drills and carbide drills with drill speeds of 30 to 35 fpm and a feed of 0.003 in. are recommended. Re-threading or re-tapping should be avoided to prevent chipping. For grinding molybdenum, aluminum oxide, silica bonded wheels have proven satisfactory. Wheel speeds of 6,500 fpm should be used with a maximum depth of grind of 0.0002 in. Grinding should always be performed with plenty of coolant. Highly polished surfaces similar to the best chromium plate can be obtained by using standard buffing wheels.

Welding Characteristics

Although molybdenum can be successfully resistance welded and arc welded, the weldment usually is brittle at room temperature. This definitely poses fabrication and assembly problems for high temperature structural applications, particularly when the uses involve forming and joining molybdenum sheet.

The problem of ductile molybdenum weldments is intimately connected with the general problem of molybdenum brittleness discussed earlier in this article. Since unworked cast molybdenum and recrystallized molybdenum are usually brittle at room temperature, weldments involving the formation of exquiaxed grains by melting and by recrystallization in the heat zone also would be brittle. Battelle Memorial Institute, among others, is investigating the problem of the welding of molybdenum and some interesting welding experiments are being planned with the more ductile high purity molybdenum. Even with this type of material, care must be exercised in the welding operation to prevent atmospheric contamination, for the most ductile material will be embrittled by oxygen pick-up from non-inert atmospheres. Only inert gas is allowed to come in contact with the weld. Westinghouse has also investigated the use of submerged arc welding. In such a process, the consumable welding electrode is not in contact with the work, but the current is carried across the gap through a protective flux.

Hot working of the weld immediately after welding can be employed to break up the cast and equiaxed structure and to provide weld ductility. Another possibility to avoid weld brittleness is the development of welding techniques which do not put the metal in the molten condition. Spot welding without fusion and "solid state" pressure welding of molybdenum are two approaches currently being investigated. As yet it is too early to report any definite progress on this development.

Many electronic components fabricated out of molybdenum sheet are brazed with copper or silver solders. If the surfaces are clean, no flux is required. Spot or seam welders can be used. For applications in which the operating temperatures are above the melting points of copper or silver solder, tantalum foil has been employed as a brazing material with excellent results. The latter requires brazing under water to prevent oxidation.

Molybdenum, platinum and palladium eutectic alloys have also been employed. A nickel-chromiun alloy containing 2 to 3 per cent boron (Wall Colmony No. 6) has been reported to be a good brazing alloy for service conditions up to 2,000 F. The presence of nickel in brazing alloys is considered helpful.

Furnace brazing of heavier molybdenum sections requires the use of hydrogen or inert atmospheres; siliconizing after brazing is not recommended. Molybdenum has also been successfully joined by riveting operations using "moly" rivets.

Alloys of Molybdenum

The striking high temperature properties of commercially pure molybdenum have led, naturally, to investigations of molybdenum base alloys that would possess superior properties. Numerous contemplated high temperature structural applications require higher strength properties than exhibited by pure molybdenum.

The Climax Molybdenum Company, under Office of Naval Research contract, is conducting a comprehensive investigation of arc-cast molybdenum alloys, and has recently reported the results of the study of binary molybdenum rich alloys. Some seventeen different alloying elements were explored, consisting mainly of the transition elements. Table VII summaried the hardening effects of the various elements investigated. The potent effects of many of the elements on increasing the hot hardness of molybdenum are shown in Figs. 13 and 14. Nickel, cobalt and iron appear to be potent alloying elements for increasing high temperature tensile strength and hardness, as does beryllium. However, high

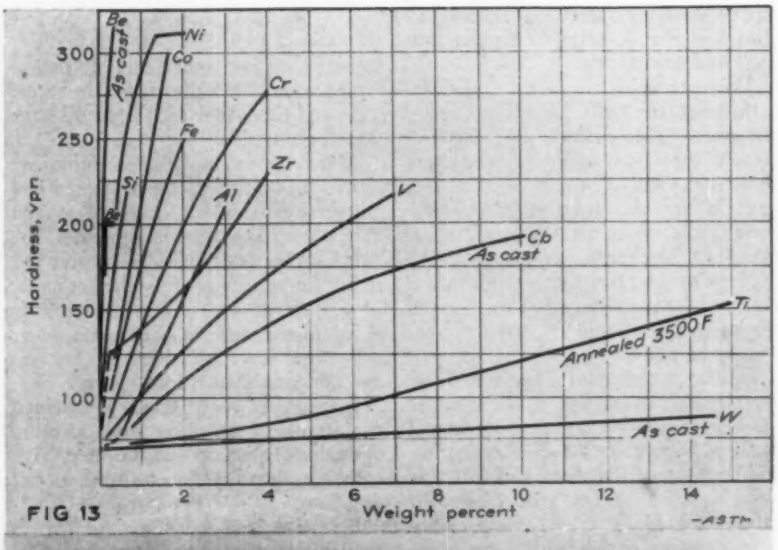


Fig. 13—Hot hardness of molybdenum base alloys. Specimens were cast and annealed at 2,400 F except where noted. As can be seen, nickel, cobalt, and iron are potent additions for increasing strength and hardness.

hardness complicates fabrication. Only nominal amounts of alloying additions —much less than the solid solubility limits of the alloying element at the forging temperature—are permissible without exceeding forgeability limits. A recent study of molybdenum-base alloys made by powder-metallurgy techniques, indicated that the amount of useful alloying additions was generally less than one per cent.

The hardness of arc-cast molybdenum is 1,600 F is about 70 VPN and only alloys that are lower than 90 VPN are forgeable. However, material with higher hardness values can be extruded. Indications are that with hot working of the alloys at 1,600 F hardnesses as high as 180 VPN are possible if suitable extrusion dies could be developed. Molybdenum alloys themselves might serve as the die materials. It is apparent, that for the present at least the dilemma is the necessity of developing materials which resist plastic flow at temperatures of 2,000 F and higher and the practical situation of having to work these alloys at these temperatures. Until hot working techniques can be developed, to utilize the full strengthening potentialities of alloying elements, the selection ot an alloy for applications requiring hardness and strength at elevated temperatures will involve compromises between the desired hardness and the ability to hot work the alloy. For certain shapes and applications, processing alloys by powder metallurgy techniques may prove to be feasible.

The molybdenum-beryllium alloys studied by Climax exhibited interesting reactions to heat-treatments. The hardness of these alloys probably can be controlled by heat-treatment, since they displayed precipitation hardening characteristics that are currently being more fully explored.

The hardness of an annealed Mo-Be 0.15 per cent alloy is about 230 Vickers hardness. Quenching from above 3,000 F raises the hardness to 430 VPN. Appropriate aging treatments increases this hardness still further to a maximum of about 675 VPN. The hot hardness of a fully aged sample is about 570 VPN at 1,400 F and 520 VPN at 1,600 F. Overaging at 1,750 F is slow and it appears that the elevated temperature strength and hardness of precipitation hardened Mo-Be alloys can be maintained for appreciable periods of time in service, at operating temperatures up to 1,750 F.

The development of heat-treatable alloys will allow the application of working and hardening techniques so commonly used in the steel and nonferrous industries. Softening heat-treatments would permit forging or extrusion and by appropriate heat treatment, full hardening potentialities of the metal can be developed. It is quite conceivable that molybdenum-beryllium alloys may occupy a similar position to molybdenum alloys as copper-beryllium does to copper base alloys.

All of the elements investigated, with the exception of carbon raised the recrystallization temperature. Titanium alloys exhibited the highest recrystallization temperatures, and in addition, exhibited the best retention of work hardness after annealing. Some recent tests indicate that titanium alloys exhibit significantly increased creep-rupture properties over unalloyed molybdenum at temperatures over 1,800 Fahrenheit.

Of course, the alloying work to date

Table VII—Relative Ability of Various Elements to Harden Molybdenum

	Vickers hardness at room temperature (As cast or annealed)	Vickers hardness at 1,600 F (Annealed)	Dynamic hardness at 3,000 F
Highest Hardness	Be	Be	Be
	Ni, Si	Ni, Si	Fe Co
	Co	Co	Cr, Zr
	Fe	Fe	Al
	Al	Cr	W, V
	Cr, Zr	Zr, Al	Ti
	V	V	
	Ta, Ti, Cb	Cb	
Lowest Hardness	W	Ti	
		W	

Table VIII—Creep Properties of Molybdenum Alloys*

Alloy Addition, percent in weight	Rupture time, hr.	Total elongation, percent	Creep Rate (Second Stage) percent per hr
0.15 Si	263	5.6	0.011
20 W	234	7.9	0.019
0.15 Co	163	7.2	0.022

* At 1,800 F and 20,000 psi. Specimens were nickel clad to prevent oxidation. **(Batelle Memorial Institute)**

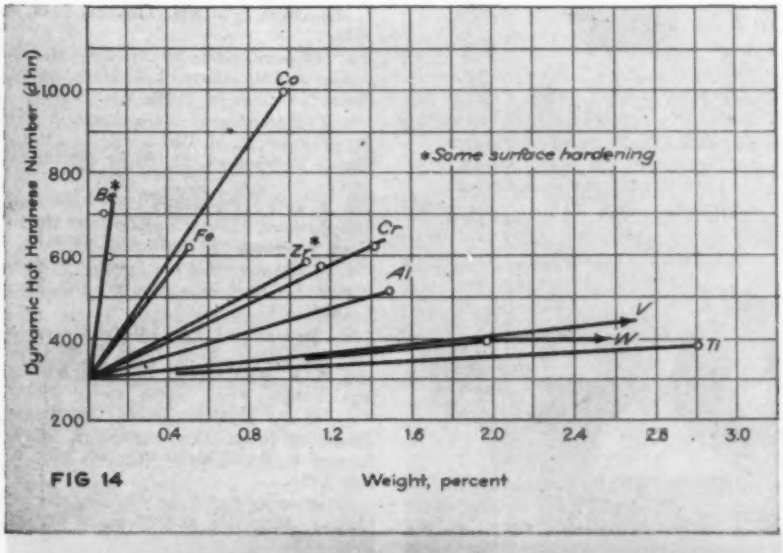


Fig. 14—Dynamic hardness of molybdenum base alloys after one hour at 3,000 F. These materials contained smaller amounts of alloying elements than those in the previous illustration. Fabrication problems limit additions.

is preliminary, and considerable more work is required before final conclusions can be drawn concerning useful alloys. Climax is still continuing its program on alloy forgeability, development of improved alloys, improvement of properties by heat-treatment, and deoxidation studies, all aimed at development of useful refractory molybdenum base alloys. The most promising of the alloys are being intensively studied to determine optimum composition ranges and to establish desired engineering data.

Battelle studies with powder-metallurgy alloys for the U. S. Air Force, supported these findings. Binary and ternary alloys were investigated and the outstanding creep-rupture properties of all the alloys tested are shown in Table VIII. Under similar conditions, molybdenum ruptures in less than 50 hours.

Westinghouse is marketing a proprietary alloy, known as "M2A", that has greater strength and ductility than pure molybdenum. In comparison with molybdenum, for drawn and annealed wire, the M2A alloy is about 25 per cent stronger. For worked material, the alloy ranges from 17 to 75 per cent stronger and has appreciably more ductility. Its high temperature hardness, as measured up to about 1,100 F, is also superior.

Applications and Future

The major interest in molybdenum and molybdenum alloys as high temperature materials is directed primarily toward gas turbine blading, combustion chambers, and similar applications. Thompson Products Company is now engaged in the development of molybdenum turbine blades, Fig. 15. The alloys that have been developed to date have the requisite high temperature strength properties, but better protective coatings and greater toughness are needed before molybdenum alloys will be fully accepted as blading materials.

Aside from potential high temperature applications, there are other industrial usages for which molybdenum and molybdenum base alloys may prove practical. Their use as die materials for die-casting brass and other relatively high melting alloys appears most promising. Piping, tubing, liners and valve applications in the chemical and related industries can take advantages of its non-corrosion properties. Its use for metal working tools appears likely. There is little doubt that as a result of government and industrial programs now underway molybdenum will soon occupy a competitive position as a structural engineering material.

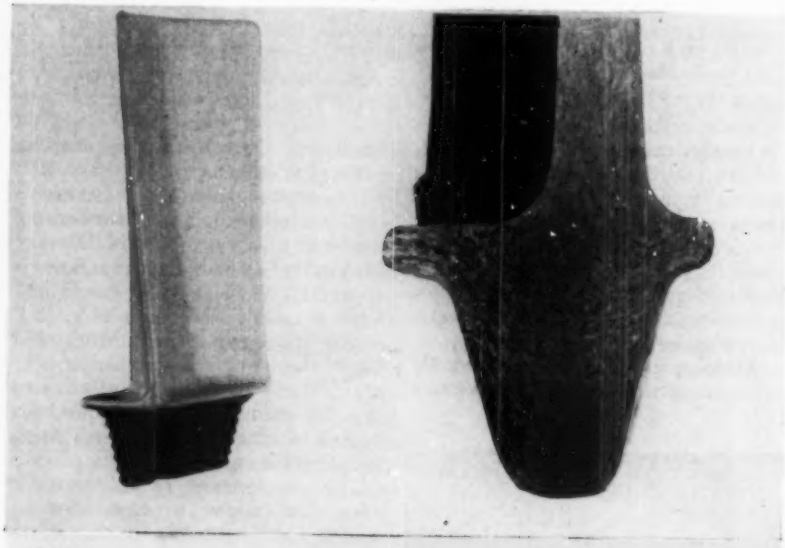


Fig. 15—Molybdenum turbine blade currently under development by Thompson Products Company, and an etched cross section of the rough forging. Upset and first blockdown were performed at 1,800 F, while the second blockdown and coining operations were done at 2,000 F.

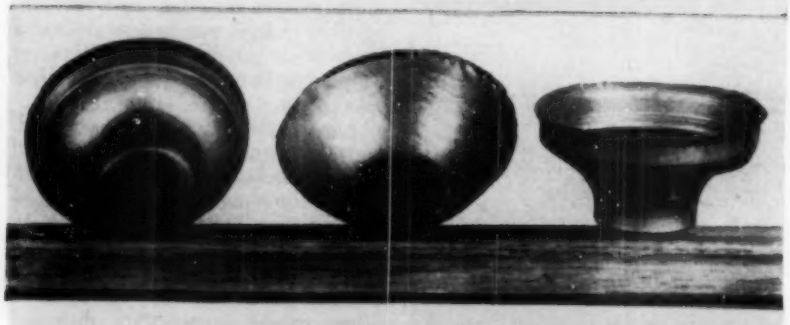


Fig. 16—Spun cups. Molybdenum can be formed by spinning at temperatures between 200 and 400 F. Aluminum bronze tools, or tools made of other materials with a low coefficient of friction are preferred.

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Bending Roll Design Analysis

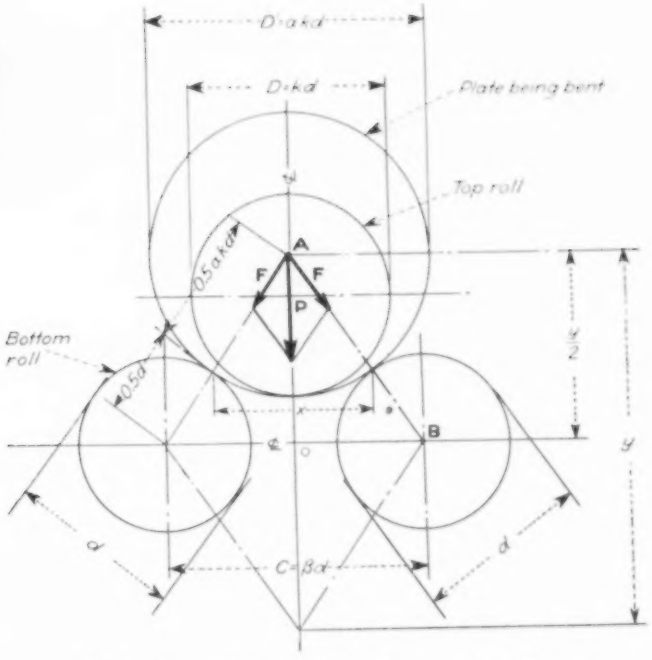


Fig. 1—Pyramid type bending roll machine and diagram of forces acting on the rolls and plate being formed.

Method for calculating data needed for the detail design of pyramid type bending rolls. Forces acting on rolls are analyzed and equations derived for diameters of top and bottom rolls to curve plate of different widths and thicknesses.

E. A. RANDICH

IN THE DESIGN of all metal working machines, before the engineer can proceed with the detail design of frames, housings, journals, bearings and gears, he must know the forces and work loads present in the fabricating operations. Such knowledge frequently can be obtained only by tedious and painstaking study and analysis.

The objective of this article is to present an accurate method that facilitates the calculation of the data needed for the detail design of bending rolls.

Assume that a pyramid type of bending machine is to be designed, in which rolls of equal length L are disposed as shown in Fig. 1. The bottom rolls have a diameter d and are spaced on a center distance C equal to βd. The top roll has a diameter D equal to kd. The material in the rolls has a modulus of elasticity E. The rolls are to curve plate to a minimum diameter D' equal to αkd. The plate material to be formed has a yield point stress of S_y psi.

The top roll is loaded with the force P required to bend the plate, and the plate is supported at the points of tangency by the bottom rolls. The force P is the resultant of two equal component forces F that act normal to the surfaces of the bottom rolls at the points of plate tangency.

Where point A in Fig 1 is the center of curvature of the smallest diameter to which the plate is to be rolled and neglecting the thickness of the plate, the relation between P and F is given by similar triangles as

$$\frac{P}{F} = \frac{y}{d(0.5 + 0.5\,\alpha\, k)} \qquad (1)$$

and

$$\frac{y^2}{4} = (0.5d + 0.5\,\alpha\, kd)^2 - (\beta d/2)^2$$

or

$$y = d\,\sqrt{(1 + \alpha k)^2 - \beta^2}$$

which when substituted in Eq (1) gives

$$\frac{P}{F} = \frac{\sqrt{(1 + \alpha k)^2 - \beta^2}}{0.5\,(1 + \alpha k)} = 2\sqrt{1 - \frac{\beta^2}{(1 + \alpha k)^2}} \qquad (2)$$

For the conditions that the rolls are simple beams uniformly loaded and that all rolls have the same deflection at their centers

$$f_1 = f_2 = \frac{5\ PL^3}{384\ EI_1} = \frac{5\ FL^3}{384\ EI_2} \qquad (3)$$

then for solid rolls made of the same material

$$\frac{P}{F} = \frac{I_1}{I_2} = \frac{\pi\,(kd)^4/64}{\pi\, d^4/64} = k^4 \qquad (4)$$

When the plate is being rolled to the minimum diameter D' equal to αkd, the distance x (Fig. 1) between the points of bearing of the plate on the lower rolls from similar triangles is

$$x = \frac{(\beta d)\ (0.5\ \alpha\ kd)}{0.5d + 0.5\,\alpha\ kd} = \frac{\alpha\beta\ kd}{1 + \alpha k} \qquad (5)$$

Considering the plate to be loaded as a simple beam, the bending moment M_P on the section of the plate midway between the bottom rolls is

$$M_P = \frac{Px}{4} = \frac{\alpha\beta\ kd\ P}{4(1 + \alpha k)} \qquad (6)$$

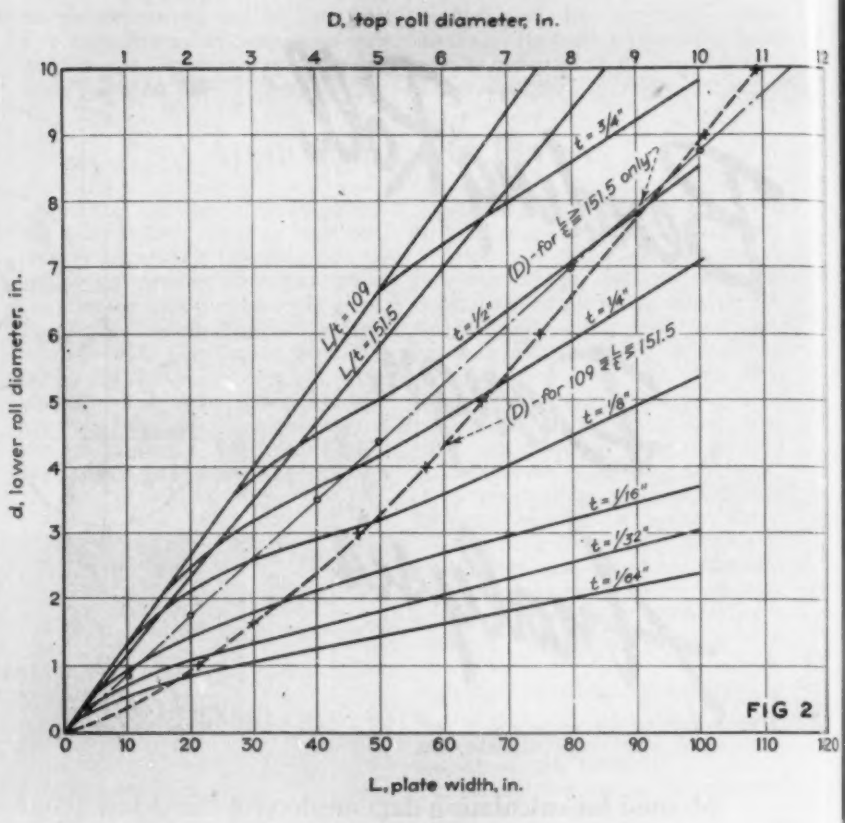
For a plate of rectangular cross-section of thickness t and width L and having a yield point S_y, the moment M_P required to bend the plate is

$$M_P = S_y\, Lt^2/6 \qquad (7)$$

Design curves similar to those shown in Figs. 2 and 3 can be readily constructed from simple logarithmic formulas that can be derived for plates of different physical properties and for bending rolls of various proportions and center distances.

Fig. 2—For conditions as cited in the example: The solid line curves give d when L/t is greater than 109; the broken line-and-dash curve gives D as a function of d when L/t is greater than 151.5; and the dash line curve gives D as a function of d when L/t is less than 151.5 but greater than 109.

Fig. 3—For conditions as cited in the example; the solid line curves give d, and the dash line curve gives D as a function of d, for L/t ratios less than 109.



Equating Eqs (6) and (7)

$$P = \frac{2\,S_y\,L t^2\,(1+\alpha k)}{3\alpha\beta\,kd} \qquad (8)$$

Considering the top roll to be a uniformly loaded simple beam, the bending moment M_R required to produce a maximum stress S_1 in the outside fibers of the top roll is

$$M_R = \frac{PL}{8} = \frac{\pi\,D^3 S_1}{32} = \frac{\pi\,k^3 d^3 S_1}{32} \qquad (9)$$

or

$$P = \pi\,k^3 d^3 S_1/4L \qquad (10)$$

By the same reasoning, the relation between the load F on the bottom rolls and the maximum stress S_2 in the outside fibers of the bottom rolls is

$$F = \pi\,d^3 S_2/4L \qquad (11)$$

From the condition that all rolls have the same deflection at their midlengths, from Eqs (4), (10) and (11)

$$S_2 = S_1/k \qquad (12)$$

By equating Eqs (3) and (10) the relation

$$S_1 = 4.8\,Ekdf_1/L^2 \qquad (13)$$

is obtained, which inserted in Eq (10) gives

$$P = 3.77\,k^4 d^4 f_1 E/L^3 \qquad (14)$$

Finally, the relation between d, f_1, S_y, L and t is obtained by equating Eqs (8) and (14), which yields

$$d^5 = \frac{S_y L^4 t^2\,(1+\alpha k)}{5.66\,\alpha\beta\,k^5 f_1 E} \qquad (15)$$

The diameters of the bottom and top rolls of a bending machine for rolling plate of any width and thickness can be calculated from Eq (15) for the conditions that: All rolls are made from materials having the same modulus of elasticity; all rolls have the same length; and all rolls have the same deflection at their mid-length.

As an example to demonstrate how the design proceeds from Eq (15), assume that a steel plate of width L and thickness t, having a modulus of elasticity of 29,000,000 psi and a yield stress of 45,000 psi, is to be rolled to a diameter not less than 1.5 times the diameter of the top roll; a fiber stress of 15,000 psi in the rolls is not to be exceeded during rolling; the maximum allowable deflection of the rolls is 0.001 in. per in. of roll face; and the center distance between the bottom rolls is to be 1.5 times their diameter. From these requirements

$E = 29{,}000{,}000 \qquad S_y = 45{,}000$
$f = 0.001L \qquad \alpha = 1.5 \qquad \beta = 1.5$

Then for Eq (15), the quantities k and d are unknown.

Calculate k by equating Eqs (2) and (4) results in the relationship

$$k^4 = 2\sqrt{1 - \frac{1.5^2}{(1+1.5k)^2}}$$

from which $k = 1.135$

Putting these values in Eq (15)

$$d^5 = 0.174\,L^3 t^2 \qquad (16)$$

taking the logarithm of both sides, Eq (16) becomes

$$\log d = (3\log L + 2\log t - 0.75)/5$$
$$\log d = 0.6\log L + 0.4\log t - 0.15 \qquad (17)$$

With value of d as calculated from Eq (17), the distance x from Eq (5) is

$$x = \frac{1.5 \times 1.5 \times 1.135d}{1 + 1.5 \times 1.135} = 0.945d$$

the bending moment from Eqs (6) and (7)

$$M_P = 0.2362\,Pd = 7{,}500\,Lt^2 \qquad (18)$$

or

$$Pd = 31{,}785\,Lt^2 \qquad (19)$$

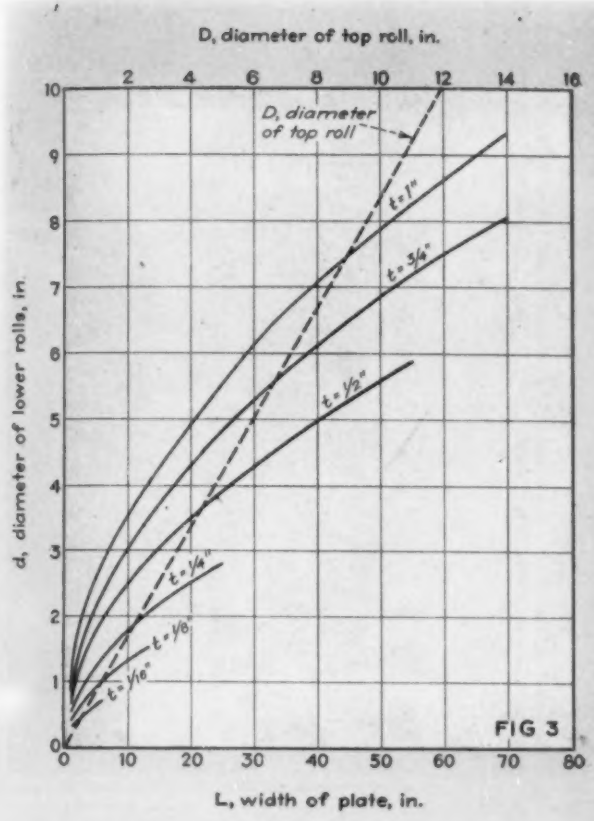
From Eq (10)

$$PL = 1.15\,d^3 S_1 \qquad (20)$$

Combining Eqs (3) and (20)

$$S_1 = 158{,}100\,d/L \qquad (21)$$

From Eq (21) it can be seen that the stress S_1 is greater than 15,000 psi when the L/d ratio is 10.55 or smaller. From Eqs (12) and (21), the stresses S_1 and S_2 are greater than 15,000 psi



NOMENCLATURE

- d = diameter of bottom rolls, in.
- D = diameter of top roll, in.
- k = ratio D/d
- D' = minimum diameter to which plate is to be curved, in.
- α = ratio D'/kd
- C = distance between centers of bottom rolls, in.
- β = ratio C/d
- S_y = yield point stress of plate material being formed, psi
- S_1 = maximum stress in outside fibers of top roll, psi
- S_2 = maximum stress in outside fibers of bottom roll, psi
- P = load on top roll, lb
- F = load on each bottom roll, lb
- L = length of roll faces, in.
- t = thickness of plate being formed, in.
- M_p = maximum bending moment on plate, in. lb
- M_2 = maximum bending moment on top roll, in. lb
- E = modulus of elasticity of roll material, psi
- I_1 = moment of inertia of section of top roll, in.^{4}
- I_2 = moment of inertia of section of bottom roll, in.^{4}
- f_1 = deflection at center of top roll, in.
- f_2 = deflection at center of bottom roll, in.

when the L/d ratio is 9.29 or smaller.

Since from Eq (16)

$$(L/d)^3 = 5.76\,(L/t)^2$$

for the critical ratio L/d equal to 10.55, the relationship between L and t is

$$L = 151.5t$$

and for the critical ratio L/d equal to 9.29, their relationship is

$$L = 109t$$

From these relations, to obtain a roll stress of not more than 15,000 psi it can be concluded for the conditions assumed in this example that:

A. When the width of the plate is equal to or greater than $151.5t$, Eq (17) can be used to calculate the diameter of both the top and the bottom rolls. When the L/t ratio is less than 151.5 but greater than 109, Eq (17) can be used to calculate the diameter of only the bottom rolls. In Fig. 2 the solid line curves give the relations between d, L and t for values of L/t greater than 109, and the relation between d and D when L/t is greater than 151.5 is given by the broken line-and-dash curve.

B. When the width of the plate is between $109t$ and $151.5t$, the top roll diameter must be increased to reduce the stress in this roll.

For Case B, an equation for the diameter of the top roll is formed by combining Eqs (9) and (19) and setting S_1 equal to 15,000 psi, whence

$$D = 1.39\,\sqrt[4]{(Lt)^2/d}$$

In Fig. 2 the relation between d and D when the L/t ratio is less than 151.1 but greater than 109 is given by the dash line curve.

C. When the plate width is equal to or less than $109t$, the diameter of all rolls should be increased.

For Case C, when the stress in all rolls exceeds the permissible stress of 15,000 psi, the roll diameters are determined from the condition that the bending stresses in the three rolls are equal rather than their deflections.

The stress S_1 in the top roll and the stress S_2 in the bottom roll are given respectively by

$$S_1 = 4\,PL/\pi D^2, \text{ and } S_2 = 4\,FL/\pi d^2$$

then for the condition that S_1 equals S_2

$$P/F = (D/d)^2 = k^2$$

which when substituted in Eq (2) gives

$$k = 1.19$$

With k equal to 1.19, the new value for x is calculated by Eq (5) to be

$$x = 0.953d$$

From Eqs (6) and (7)

$$\frac{0.953dP}{4} = \frac{45{,}000\,LT^2}{6}$$

or

$$P = 31{,}500\,L_1t^2/d$$

substituting this value of P and the value 1.19 for k in Eq (9), the diameter of the bottom roll is

$$d = 1.12\,\sqrt{L\,t}$$

and since D equals kd

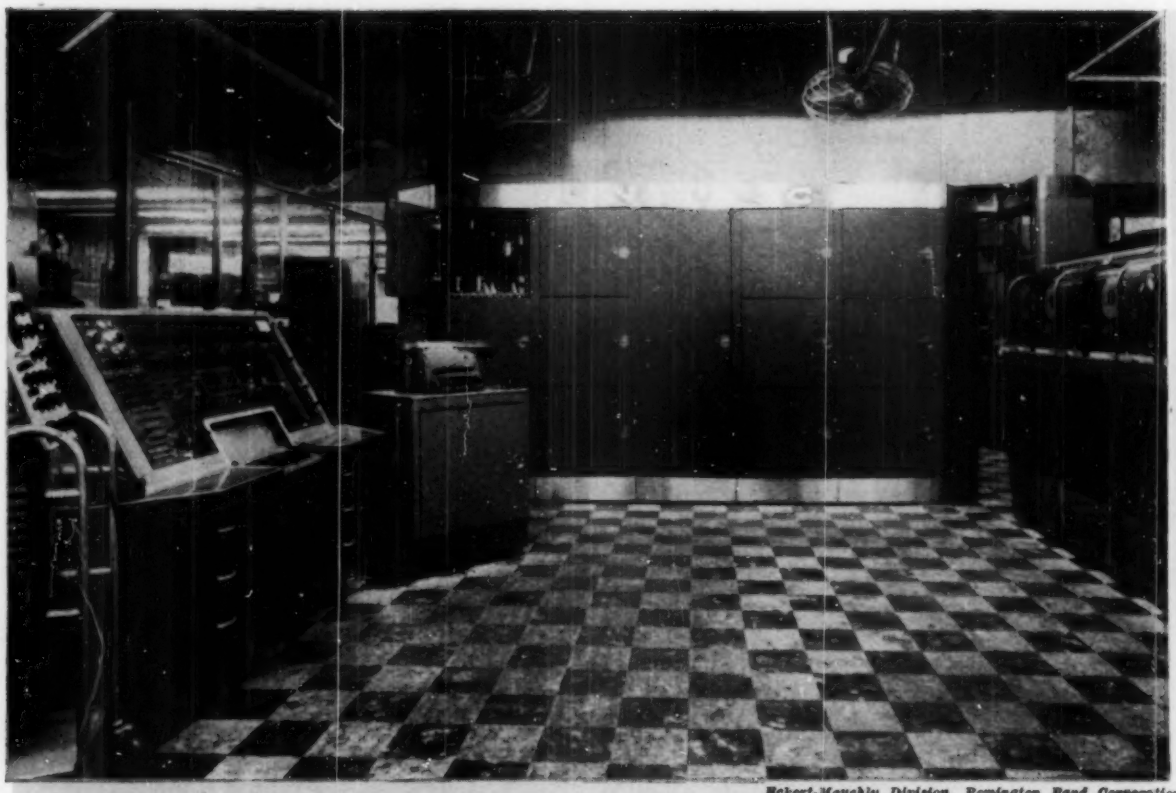
$$D = 1.19\,d$$

A formula similar to Eq (17) can be written for D the diameter of the top roll as

$$\log D = 0.5\,L + 0.5\log t + 0.1248$$

For L/t ratios less than 109, the curves of Fig. 3 give the diameter of the lower rolls as a function of plate width and thickness, and the diameter of the top roll as a function of the diameter of the bottom rolls.

The foregoing analysis and procedure can be applied to the design of rolls for curving nonferrous plates as well as for the different grades of steel plate. For plates of different materials the constants, of course, vary with yield strength, tensile strength, maximum allowable fiber stress, diameter to which plate is to be rolled, and center distance of bottom rolls.



Eckert-Mauchly Division, Remington Rand Corporation

Fig. 1—UNIVAC digital computer is composed of several units: From left to right are the master control where "programming" is initiated; UNITYPER which prints data on magnetic tape; the UNIVAC proper, which performs calculations called for by "instructions" on the tape; and UNISERVOS, which feed tape into and receive calculations from the main calculator. This equipment carries calculations as discrete numbers and has high arithmatical accuracy.

Organizing a Computer

F. P. COZZONE
Lockheed Aircraft Corporation

AUTOMATIC COMPUTING MACHINERY is becoming an increasingly important factor in design and analysis procedures because it reduces the time necessary to perform elaborate basic calculations. In many cases it permits the substitution of a rigorous engineering analysis for a trial-and-error design procedure.

In the aircraft industry, the initial work with automatic computing machines developed when it was found that IBM digital computing equipment showed a direct cost advantage over manually operated desk calculators for handling the numerical reduction of many involved problems such as the determination of structural section properties, unit beam analysis equations, and in the solution of the flutter analysis matrix equations. In such cases, the computations were already being performed manually and the contribution of the automatic machines was to reduce both the direct cost and the elasped time to accomplish the work.

More recently, two fundamentally different types of analogue computers have been developed and are being widely used to solve a great variety of engineering problems. In addition, there has been substantial improvement in digital machines to extend their practical usage. These equipments have been successfully adapted by many industries including airframe manufacturers to obtain solutions to problems that have hitherto defied rigorous analysis, such as problems of transient dymanic loading and of stability and control. Here the direct cost of obtaining the solution has not been of primary importance because the solution of the problems might readily provide the difference between an initially satisfactory product and a product that could be used only after a long and costly trial and error development program.

In a study of engineering computing facilities, it is not a matter of whether the engineering department should set up computing facilities, but rather, a question of how large a facility and what type of equipment are needed. Generally, it is not possible to justify the initial use of automatic computing machinery on a direct dollar cost basis because the

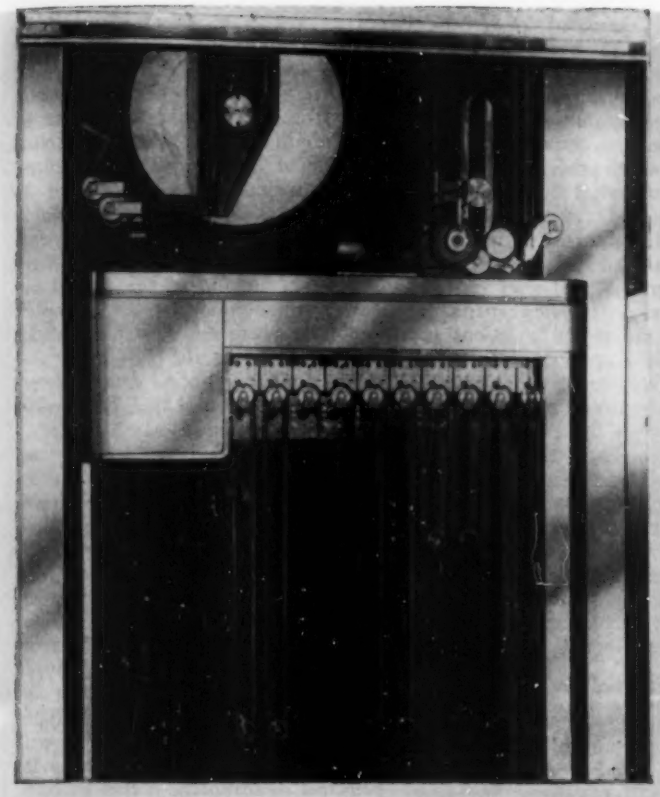


Fig. 2—Three punched-hole memory units are part of the IBM Selective Sequence Electronic Computer. Each consists of ten reading stations and a device for punching intermediate results in tapes for use in later phases of a calculation. Equipment is also called the "Defense Calculator".

Table I
Typical Operations Handled by a Card Programmed Calculator

1. Construction of mathematical tables.
2. Differencing to any order desired.
3. Interpolation using first, second and higher order differences.
4. Numerical integration.
5. Harmonic analysis.
6. Solution of simultaneous equations.
7. Multiplication of series.
8. Matrix and determinate calculations.
9. Method of least squares.
10. Differential equations.
11. Fourier analysis.
12. Successive approximation methods.
13. Curve fitting.
14. Systematic handling of linear arrays.
15. Partial differential equations.
16. Systematic sorting.
17. Random sampling.
18. Data reduction.

Center *in the Engineering Department*

functions of the machines will not directly replace existing functions, and the advantages obtained will be in the more nebulous terms of advancement in the "state of the art", better design and improved competitive position. It therefore requires top-level policy decisions to set up the required facilities and to establish an effective organization to be responsible for developing techniques and procedures for applying automatic computing equipment to the solution of engineering problems.

Types of Computers

Computing equipment can be classified in two general types—digital and analogue. The digital type is defined as equipment that carries calculations as discrete numbers with complete arithmetical accuracy to the number of significant figures specified. Typical calculators of this type are: The IBM Card Programmed Computer, IBM Selective Sequence Electronic Computer ("Defense Calculator"), Eckert-Mauchly "EDVAC" (Electronic Discrete Variable Calculator), "MANIAC" (Developed at Princeton University under Army Ordnance sponsorship), and the Remington Rand "UNIVAC" shown in Fig. 1 on facing page.

Standard machines use cards only to represent numbers in the particular operation or sequence of operation to be performed as determined in advance by the position of wires that the operator inserts in a plug board. Thus, the computing routine cannot, in general, be changed without stopping the machine and performing time-consuming manual manipulations. In the card programmed calculator, the program for calculation is contained on a deck of cards fed into an accounting machine. Holes punched in the cards signify both numbers and instructions to the machine. Each card carries on eight-digit instruction that specifies the location and storage of the factors to be operated upon, the operation to be performed and the disposition to be made of the result. By feeding cards carrying the appropriately punched card code, a non-repetitive sequence of operation of any desired length can be carried out. The machine is set up so that some operations other than addition, subtraction, multiplication and division are already incorporated in the ma-

chine. For example, only one coded signal is required to call for the taking of a square root, sine of a function, cosine of a function, raising a number to a power, series expansion and a few other complex operations. Plug boards are also provided to take care of the computations that are repetitive.

The digital machine can basically be broken down into three units: (1) Storage unit; (2) arithmetic unit and (3) control unit. The storage unit is capable of holding forty-eight 10-digit numbers including a sign for each number. The input, as mentioned above, is on cards fed into the arithmetic unit and the output can be printed tabulated results, cards or tape. For internal storage, the calculator uses 80 mechanical counters; for external storage, cards are used. A calculator punch is used to prepare these cards and also to record on them the results of calculations. One or more supplementary units provide storage for sixteen 10-digit plus or minus numbers relayed to it from the electronic calculator. Fig. 2 shows one of three punched-hole memory units in the IBM "Defense Calculator."

When a stack of cards is run through a card programmed electronic calculator, it is capable of reading several numbers from each card and performing a complex, prescribed sequence of additions, subtractions, multiplications or divisions. It can punch one or more answers into the unused portion of the same card and also store some of the answers obtained for use in connection with the data read from the following card. Table I lists typical operations to which the card programmed calculator has been successfully adapted.

Analogue Computers

Analogue equipment is capable of working with continuous variables rather than with discrete numbers. This type of equipment can be broken down into two basic classes: (1) Operational analogue equipment, which performs specific mathematical operations on input quantities, and (2) direct component-to-component analogue equipment, which provides a means for making an equivalent mock-up of some physical system. The operational equipment consists essentially of individual units such as "adders", "multipliers" and "integrators". These can be coupled in accordance with particular algebraic or differential equations and will maintain a specific mathematical relationship between all variables while an independent variable is scanned through a range of possible values. The direct component analogue equipment, on the other hand, consists of building blocks (normally electrical inductances, capacitances, and resistances) and a means for coupling so that the mass, stiffness and damping constants of a physical structure can be simulated to provide an electrical response to any equivalent excitation.

Differential Analyzers

General-purpose operational analogue machines are called differential analyzers. Typical among these are: (1) "GEDA" (Goodyear Electronic Differential Analyzer), (2) "BEAC" (Boeing Electronic Analogue Computer), (3) Electronic Analogue Computer Components (George A. Philbrick Researches, Inc.) (4) "REAC" (Reeves Electronic Analgoue Computer) and (5) "MADDIDA" (Magnetic drum digital differential analyzer made by Northrop Aircraft).

Except for the "MADDIDA", these equipments differ only in size and degree of refinement. They are relatively simple to use for solving particular problems because they are set up directly from algebraic or differential equations and work rapidly enough to allow their use directly as a part of an operating system (Partial systems testing). Such a computer could be used to supply airplane response characteristics to close the servo system loop for making laboratory tests of an autopilot system. The main disadvantage of this equipment is a physical limitation on the accuracy of its components. Because these can rarely be better than most of the physical data on which designs are based, there arises the question of the overall accuracy of solution in some complex problems where it is desirable to make accurate solutions for both lower and upper limits of physical data to determine the effect of small changes in physical constants.

"MADDIDA" is not strictly an analogue machine. Its internal computing is done digitally and its computing accuracy is therefore not limited to the accuracy of its components. It is, however, arranged to work with continuous input and output variables, and is comparable to other differential analyzers in its capabilities. The principal advantage over the above types of differential analyzers is its six-significant-figure accuracy, though there is also reason to believe that it will be somewhat easier to maintain. Its principal disadvantage is that its computing speed is not sufficiently rapid to allow its use for partial systems testing and that function, therefore, will require other equipment.

These analyzers will handle ordinary differential equations, linear or non-linear, up to the seventh order for the "REAC" and to about the twenty-second order for "MADDIDA". They are also very useful for making cross plots of simple and complex algebraic expressions of physical phenomena for survey purposes.

Network Analyzers

Direct component-to-component analogue machines are called network analyzers and are not as available as the differential analyzers. They were initially developed, as the name implies, for analyzing electric power network systems. Both General Electric and Westinghouse Electric have developed their own and have used them extensively.

There is a distinct advantage to the use of the direct analyzer equipment since all elements of the physical system, or nearly all, have their counterparts in the analogue and as such are under the direct and independent control of the operator. To study the effect of varying a certain element of the system, the operator needs only to vary the corresponding element of the analogue. In addition to the ad-

Table II — "Routine" Problems Handled on IBM Computers

1. Reduction of experimental data
2. CAA minimum required field length determination
3. Solution of flutter matrices
4. Section properties and internal loads on shells
5. Engine performance selection
6. Fire control evaluation
7. Summary of airplane performances
8. Probability of radar detection study
9. Stability of elastically coupled bodies
10. Structural cutout analyses (iterative process)
11. Solution of fatigue strength summation equation
12. Solution of flexural pivot design curve
13. Solution of transient heat transfer
14. Harmonic analysis of experimental data
15. Least square analysis
16. Solution of simultaneous equations
17. Curve fitting

Table III — Classification of Five Computers According to Their Adaptability to Different Types of Aircraft Design Problems

Problem	Machine Adaptability					Engineering Group Concerned								
	IBM Card Programmed Calculator and Related Equipment	Defense Calculator and IBM CPC	MADDIDA	D-C Analogue Differential Analyzer	Direct Analogue Network Analyzer	Preliminary Design	Aerodynamics	Wind Tunnel	Special Project	Flight Test	Research Lab	Staff	Structural	Project
1. Airplane Stability Analysis						X	X	X		X				
2. Servomechanism Performance Analysis						X	X			X	X	X		
3. Fire Control Problems						X	X			X		X		
4. Dynamic Load Analysis						X	X				X		X	
5. System Performance Analysis						X	X			X	X	X	X	X
6. Aerodynamic Loads						X				X			X	
7. Flutter Analysis						X	X							
8. Weight Study or Analysis						X						X	X	X
9. Landing Gear Shimmy Analysis						X					X		X	X
10. Buffeting Load Analysis										X			X	
11. Heat Flow Analysis						X	X			X	X		X	X
12. Analysis of Rotating Shafts						X					X		X	X
13. Airplane Structural Life Expectancy Analysis						X					X		X	X
14. Airplane Operating Cost Analysis						X								
15. Shock Mounting Analysis and Design						X				X	X		X	X
16. Analysis of Precision of Measurements								X		X	X			
17. Atomic Energy Design Studies						X			X					X
18. Antenna Design						X					X	X		
19. Radome Design						X			X			X		X
20. Wave Guide & Transmission Line Design						X					X	X		
21. Aerodynamic Design Studies & Analysis						X	X			X				X
22. Trajectory Analysis & Determination						X	X			X		X		X
23. Optimum Design Studies (Weight, Space)						X			X		X	X	X	X

Solid black squares indicate equipment best suited for given problem; then white; then color.

vantages of a direct one-to-one correspondence between analogue elements and system elements in design work, rapid and accurate solutions of complex nonlinear problems are also obtainable.

In some of the non-linear applications, partial differential equations have had to be solved by difference equations. Computations made by means other than the direct analogue computer are extremely difficult, thus giving the direct-analogue technique a distinct advantage in engineering design and applications where the effects of many parameters have to be investigated to ensure optimum performance of the final design.

Simultaneous Equation Solvers

The only commercially available unit of this type is made by the Consolidated Engineering Corp. Sometimes called a matrix inverter, this analogue computer handles up to twelve equations and is based on successive approximations.

However, a ten-equation solver constructed by RCA Laboratories at Princeton, N. J. solves the equations directly without resort to successive approximations. The practical limit for this unit is about 25 simultaneous equations. An analogue computer which accepts equations in digital,

punched card form has been developed at the Watson Scientific Computing Laboratory in New York City.

Polynomial Root Solvers

No commercially available devices of this type are known, although a so-called electronic isograph computer recently developed by AMC at Cambridge, Mass. reportedly handles roots up to a tenth-degree polynomial. In this same category is an electrical algebraic equation solver developed at the University of Pennsylvania. This machine can determine all the roots of an algebraic equation of eighth degree having real coefficients.

Auxiliary Equipment

There has been a significant increase in the amount of data that is recorded on oscillographs, and the reduction of these data into time histories or quantitative plotted date is becoming ever more time consuming. With an oscillograph reader, it is possible to read oscillograph records with a speed and accuracy virtually impossible by manual means. One such unit is the Telereader designed by the Telecomputing Corp. and built by the Consolidated Engineering Corp. This equipment provides a 2½-times enlarged image of the data record. Included with this image is a system of movable indicating cross wires whose position is indicated on binary electronic counters to 0.001 in. (relative to some arbitrarily fixed reference axis where the counters were initially zeroed). The operator of the machine keeps the indicating cross wires constantly on the trace as it is slowly advanced by an electrical drive.

A machine that works in conjunction with the oscillograph reader is called an automatic data punch. One such unit is the Telecorder, which provides permanent data in the form of punched cards. Used alone, it displays a four-place number, the magnitude of which is a measure of the value of the recorded trace deflection at a chosen point on the record. When used with an IBM Type 517 summary punch unit, the combination is capable of punching cards at a rate of 50 per minute. For each point recorded, information punched in the card can consist of point number, primary coded counter readings, 15 digits of identification, calibration factors, zero settings and other data. Conversion of a binary number to a decimal, plus the introduction of calibration factors and zeros can be readily accomplished in one operation by the IBM calculator. The accuracy of readings for the combined Telereader and Telecorder depends almost entirely on the operator's ability to set the cross wires on the trace being read.

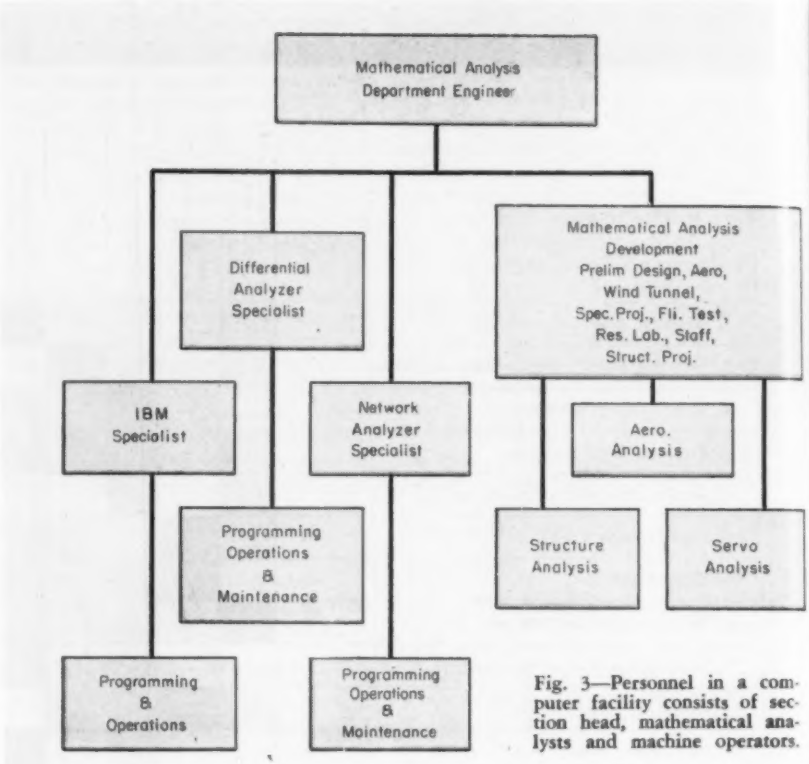


Fig. 3—Personnel in a computer facility consists of section head, mathematical analysts and machine operators.

The combination reader and data punch system works with decimal numbers directly. It appears to have some advantage for reading continuously moving records, but the Telereader and Telecorder combination is better adapted to scanning fixed records, particularly if two-coordinate reading is desired.

Other auxiliary equipment includes graph platters, data reduction devices, tape readers and punches, and decimal-to-binary (and inverse) conversion devices.

Computation Problems

Computation problems are listed in Tables II and III. The first list consists of problems that have been handled at Lockheed on IBM computing machines; the second list consists of future computation problems, some of which have been done on computing machines by other companies and some of which have not been done at all. Two classifications have been added to Table III: (1) A reference to the engineering group which has, or may have that type of problem, and (2) an indication of the relative adaptability of the machines for the solution of each type of problem. For a given problem, one type of computer is well suited, another adaptable and a third unsuited. Precise ratings for the various machines require detailed information on computer characteristics, the nature of information sought, whether a general or specific problem is studied, the relative costs of preparation, and interpretation as compared with actual computer costs and many other factors. The colored "boxes" in the center of Table III give an indication of the adaptability of various computers as they relate to 23 types of aircraft design problems. The color code is illustrated in Problem No. 2 (Servomechanism Performance Analysis). Solid black shows the Differential Analyzer is best suited for this type of study, the "MADDIDA" is next (shaded black), then the Network Analyzer (white), then the Defense Calculator (shaded color) and finally the IBM Card Calculator (solid color), which is least suited to the solution of this servomechanism problem.

Computer Facility Organization

The organization of an engineering computing facility requires the assignment of specific responsibilities for the following functions:

(1) Determination of work priorities and general administration of computing group activities.

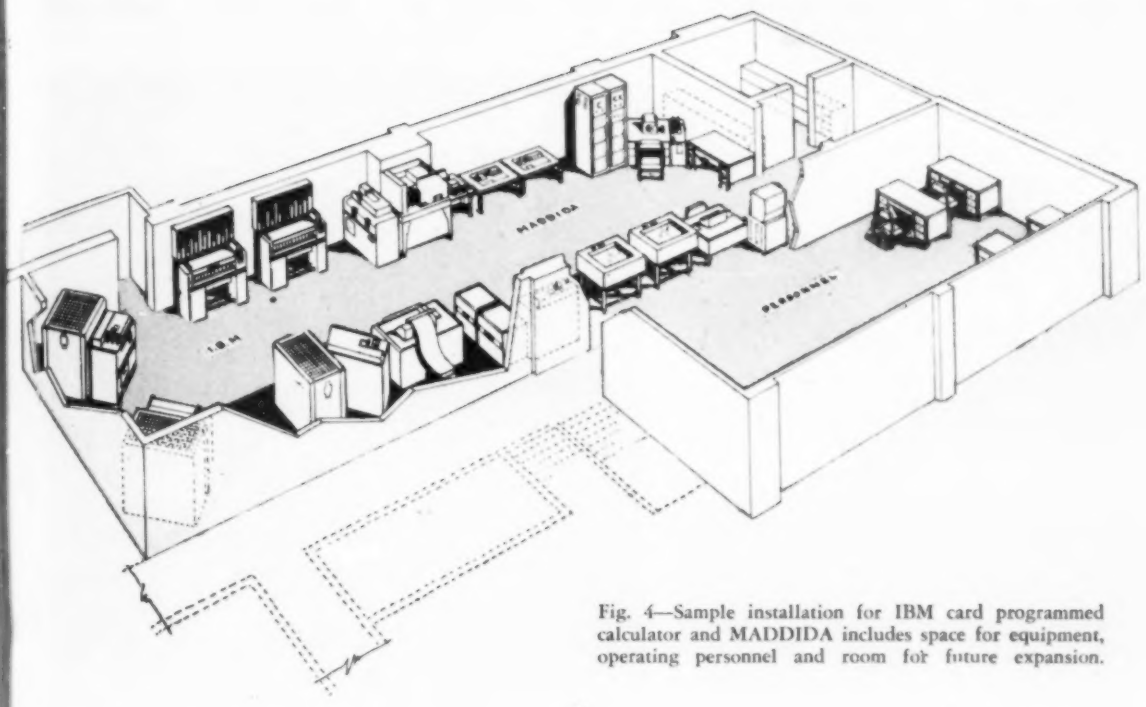


Fig. 4—Sample installation for IBM card programmed calculator and MADDIDA includes space for equipment, operating personnel and room for future expansion.

(2) Operation of computing machines.

(3) Maintenance of computing machines.

(4) Detail programming of machines (Detail breakdown of mathematical operations into machine instructions).

(5) Computing equipment development (Keeping abreast of developments in computing field).

(6) Problem analysis (Breakdown of engineering problems into forms most easily handled by machines and selection of most efficient machine for each problem).

(7) Methods Development and Research (Studies of particular engineering problems to develop improved analysis methods through use of machine computations).

Responsibilities (2) through (5) fall nautrally into an autonomous computing organization, but there are several possibilities for the assignment of (6) and (7). The responsibility for problem analysis can be set up on a purely mathematical basis by the computing organization, while methods research and development are left to the various engineering organizations where primary responsibility for methods already exists. Or problem analysis can be handled on an engineering basis by a special section of the computing organization that is also responsible for methods research and development, and acts in a consulting capacity for the engineering organization.

Methods-research and development should be basically independent of design schedules. Many applications of computing machines to engineering work require considerable development that cannot be justified on the basis of reduced cost or elapsed time on the first job on which it is used. In these instances, methods development should be carried out parallel with the normal handling of the particular problem.

The administrative head or Department Engineer (Fig. 3) is responsible for all the mathematical analysis functions pertaining to the use and exploitation of automatic computing machines. To qualify for these responsibilities, such an individual should have engineering training and experience, some background in machine computation, and some supervisory experience. In addition to these basic qualifications, it is desirable that the administrative head have experience in applied mathematics, physics and electrical engineering.

Working under the administrative head there should be specialists, one for each of the machines in the computer laboratory. These men, act as consulting experts on the capabilities of each machine and supervise personnel who operate and maintain the equipment.

The development group is responsible for contacting the engineering organizations, putting problems in forms suitable for machine computation, and the development of new methods of analysis for use with automatic computing equipment. This group should be made up of experienced engineers from each of the major branches of engineering, and should, in addition, be specially trained in problem break-down for automatic machine solution.

Space Requirements

The sketch in Fig. 4 is a sample layout of a computer facility centered around two machines—the IBM card programmed calculator and the "MADDIDA". Space is provided for card storage, auxiliary equipment and personnel operations. If future expansion of the facility is anticipated, suitable allowances should be made. In this connection, thought should be given to ventilation. Heat output for the IBM and "MADDIDA" is rated at 80,000 BTU per hr. This figure jumps considerably if the defense calculator and/or network analyzer are to be installed at a later date.

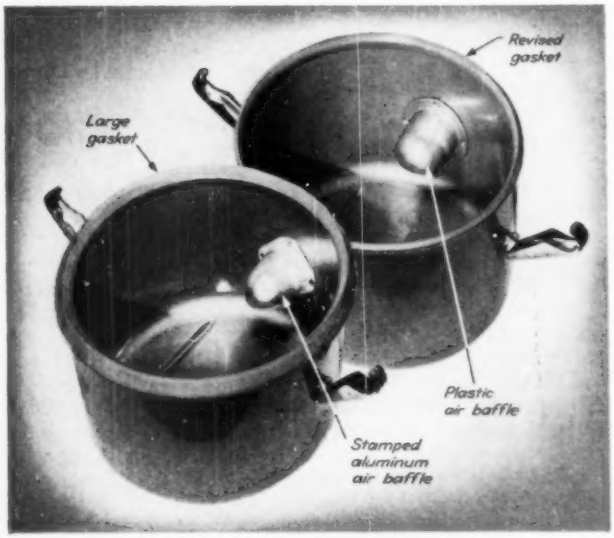
Use of Plastic Parts Improve Vacuum Cleaner

By using plastic in place of steel for some of the parts of their vacuum cleaner, the Lewyt Corporation, Brooklyn, N. Y., has improved the quality of their product and at the same time solved their material shortage problem. It has been made lighter, operates more quietly, and is more attractive with the parts made under the revised specifications. However, the material replacement did not make possible a reduction in price.

The cellulose acetate handle does not readily conduct the heat generated in normal motor operation to the operator's hand as the die cast aluminum did. The name plate is now clear polystryene, through which a design can be seen; the design is plated on the underside of the name plate by the vapor deposit method. The sound dampening qualities of the cellulose acetate air diffuser reduces noise propogation through the top assembly when the cleaner is in operation; this material replacement made possible the redesign of the diffuser to include a better exhaust air flow path and an improved appearance without any change in weight. The air inlet baffle was changed from an aluminum stamping to molded cellulose acetate and resulted in a reduction in air inlet noise by 100 percent. Material changes in the accessories include replacing the rubber brush holder to vinyl plastic to prevent accidental marking of wall and baseboards. The carpet tool has been changed from die cast aluminum to cellulose acetate plastic to make it lighter and easier to handle.

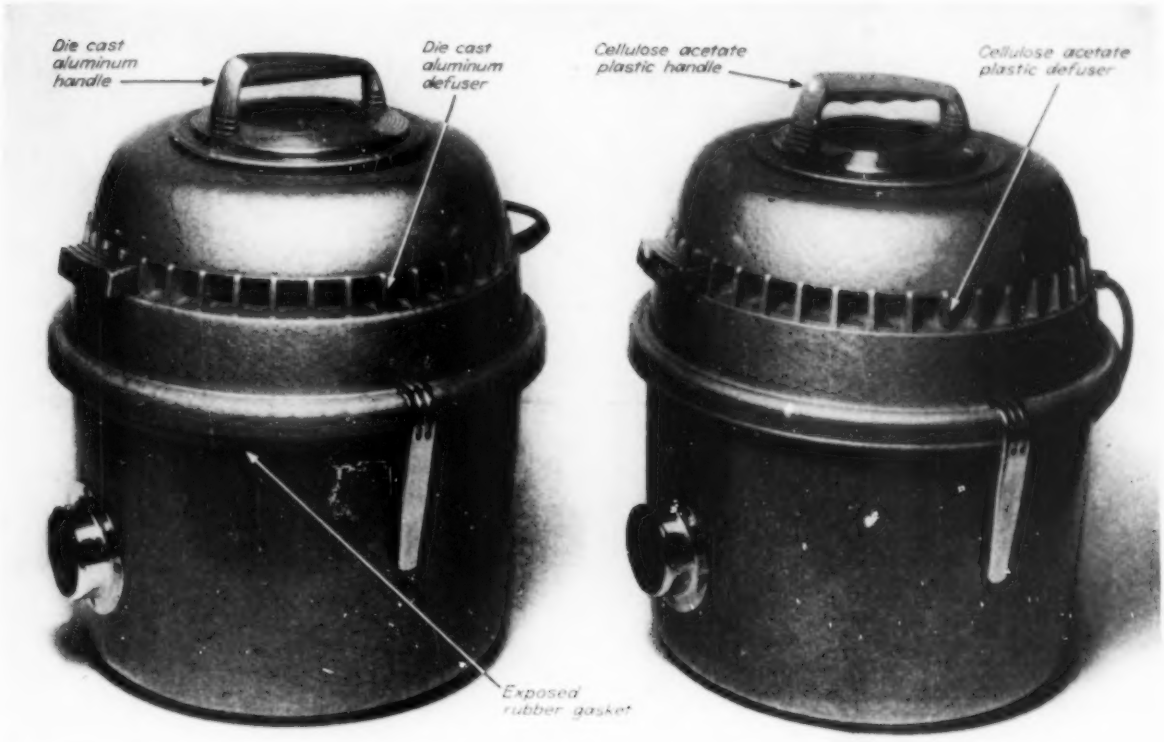
Other changes in design include substituting a disposable dust bag for the cone-shaped filter previously used. This "speed sak" has three times the effective filtering area as the cone filter had. The rubber gasket between the dust bowl and the middle sheel has been reduced in size to make a better seal and improve the general appearance of the cleaner.

REPLACING STEEL PARTS with plastic has made the Lewyt vacuum cleaner, lighter, more quiet-operating, and better in appearance. Electrical condensers on the starting switch prevent cleaner motor from interfering with radio and television reception.

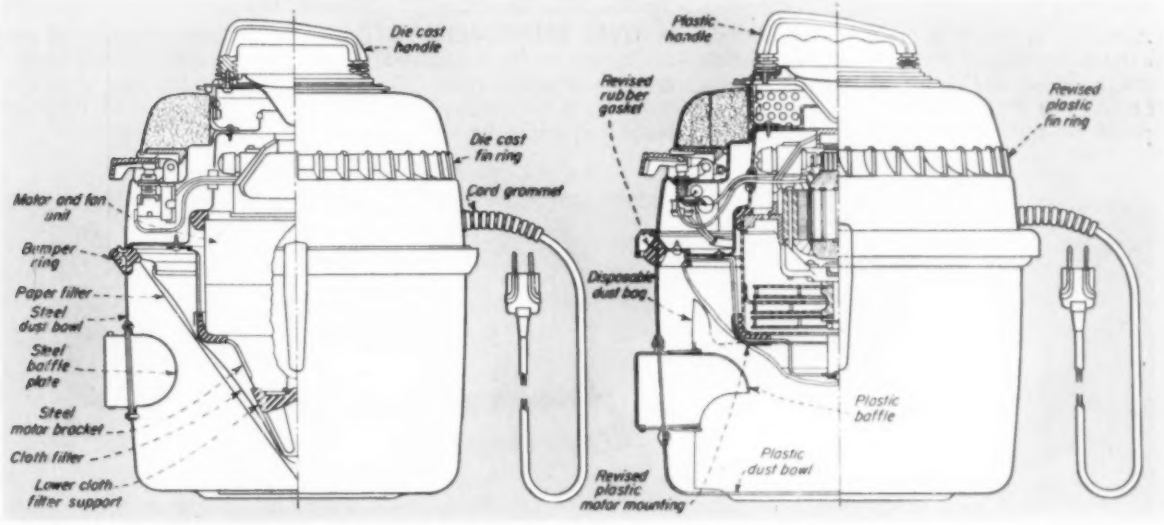


DIFFERENCE IN APPEARANCE between the steel dust bowl on the left and the reinforced cellulose acetate bowl is small, but the steel weighed 2.687 lb as compared with 1.250 lb for the plastic. The cost of the plastic bowl is double.

IN NEW PRODUCTS



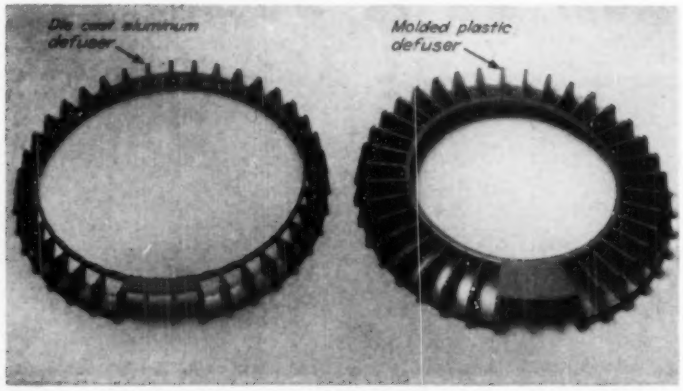
HOW THE USE OF PLASTIC has improved the canister appearance. The handle now has finger grips and the name plate is clear polystyrene with the design plated on the underside by the vapor deposit method. The plastic airdiffuser gives the exhaust holes a closed appearance. The large rubber gasket has been replaced by a small one that is removed from sight. Clearner with the plastic parts is almost identical to the one with metal parts.



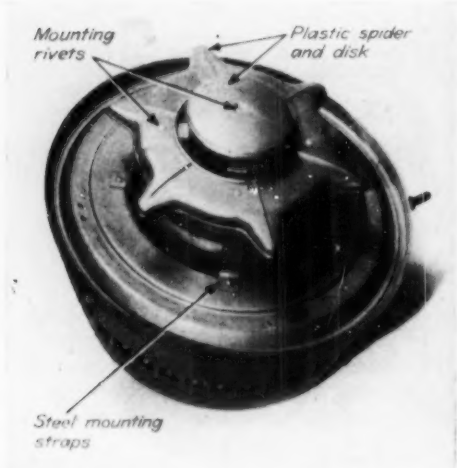
COMPARISON of the previous model at left with the revised model shows the mechanical changes that have been made. The cone shaped paper filter has been replaced by a disposable dust bag; the cloth filter has been modified and the motor bracket changed to permit the use of the new dust bag. The rubber gasket is smaller now, and hidden from view. The redesigned air diffuser has a curved air flow passage. (*continued on next page*)

Vacuum Cleaner (continued)

DISPOSABLE "speed-sak" dust bag adaptor fits snugly over the inlet baffle. The bag has three times more effective filter area than the filter cone it replaced and is more convenient.

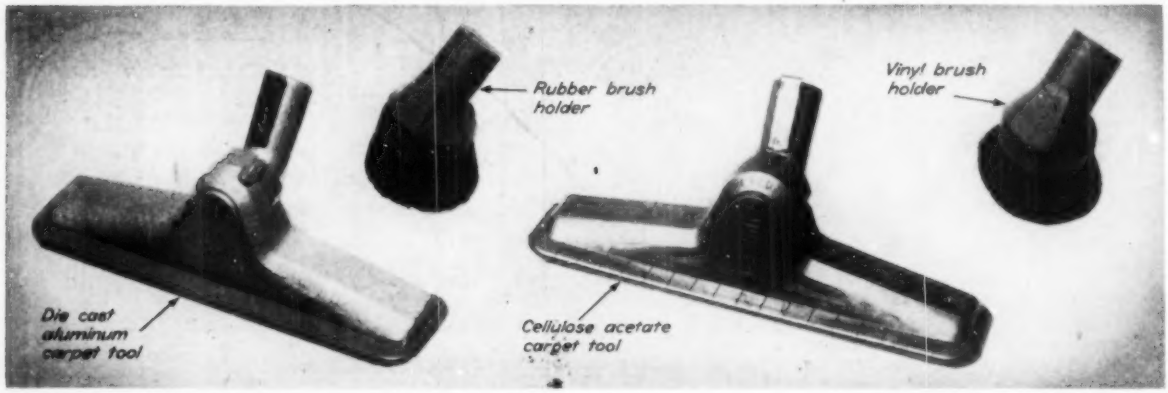


DIE CAST ALUMINUM AID DIFFUSER on the left was replaced by the molded cellulose acetate diffuser on the right. Both parts weigh the same, but the plastic permits better air flow design. The dampening qualities of the plastic have greatly reduced sound transmission.



A BOTTOM VIEW of the motor, fan and air diffuser assembly shows the new combination motor support and cloth filter support. It was necessary to change the shape of the unit to permit use of the disposable "speed sak".

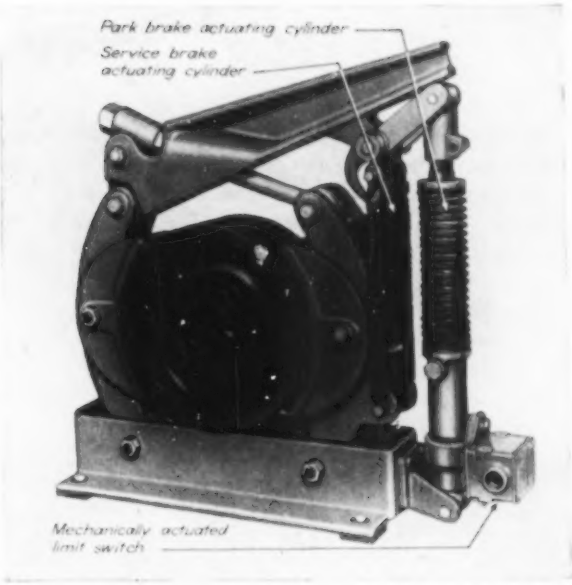
A STEEL REINFORCING STRAP is molded into the cellulose acetate handle to give it additional strength and provide a strong receiver for the self-taping screws. The predrilled hole in the strap is used to locate it in the mold. The slight bend at the center of the strap holds it square in the mold during the fabricating process.



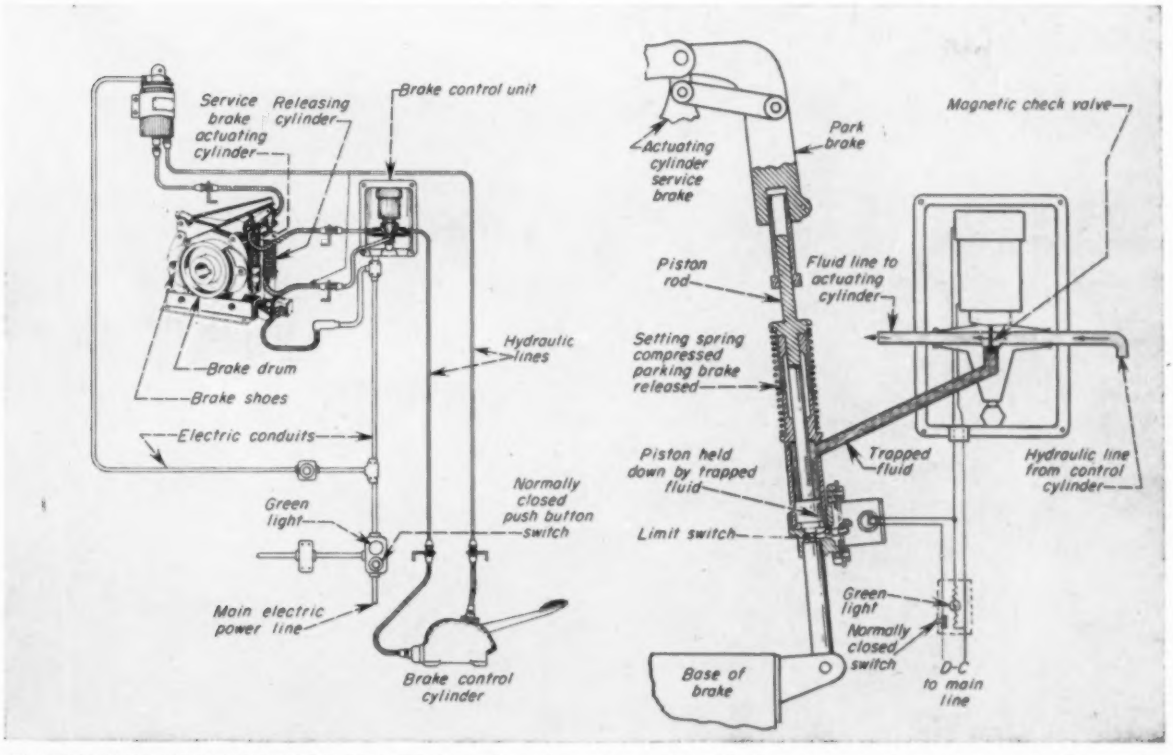
VINYL BRUSH HOLDER does not make black marks on walls, baseboards, or any place where it may touch during cleaning operations, as the rubber holder does. The cellulose plastic carpet tool is much lighter and easier to handle.

Mechanically Operated Switch Sets Crane Brake

The type HM brake system made by the Wagner Electric Corporation incorporates a combination hydraulic service brake and parking brake for use on the bridge drives of overhead traveling cranes, whirler cranes, and other types of industrial equipment which require parking brakes when out of service or while performing their principal functions. A recent improvement in the system involved the elimination of the hydraulic pressure switch located in the control box for a limit switch operated by the piston rod of the releasing cylinder. Now, changes in fluid pressure, because of temperature variation or leakage, will not endanger operation or holding power of the parking brake.



FLUID UNDER PRESSURE is trapped between the check valve and the releasing cylinder piston to hold the setting-spring compressed. The cylinders are chrome plated and all materials used on the other parts are corrosion resistant.

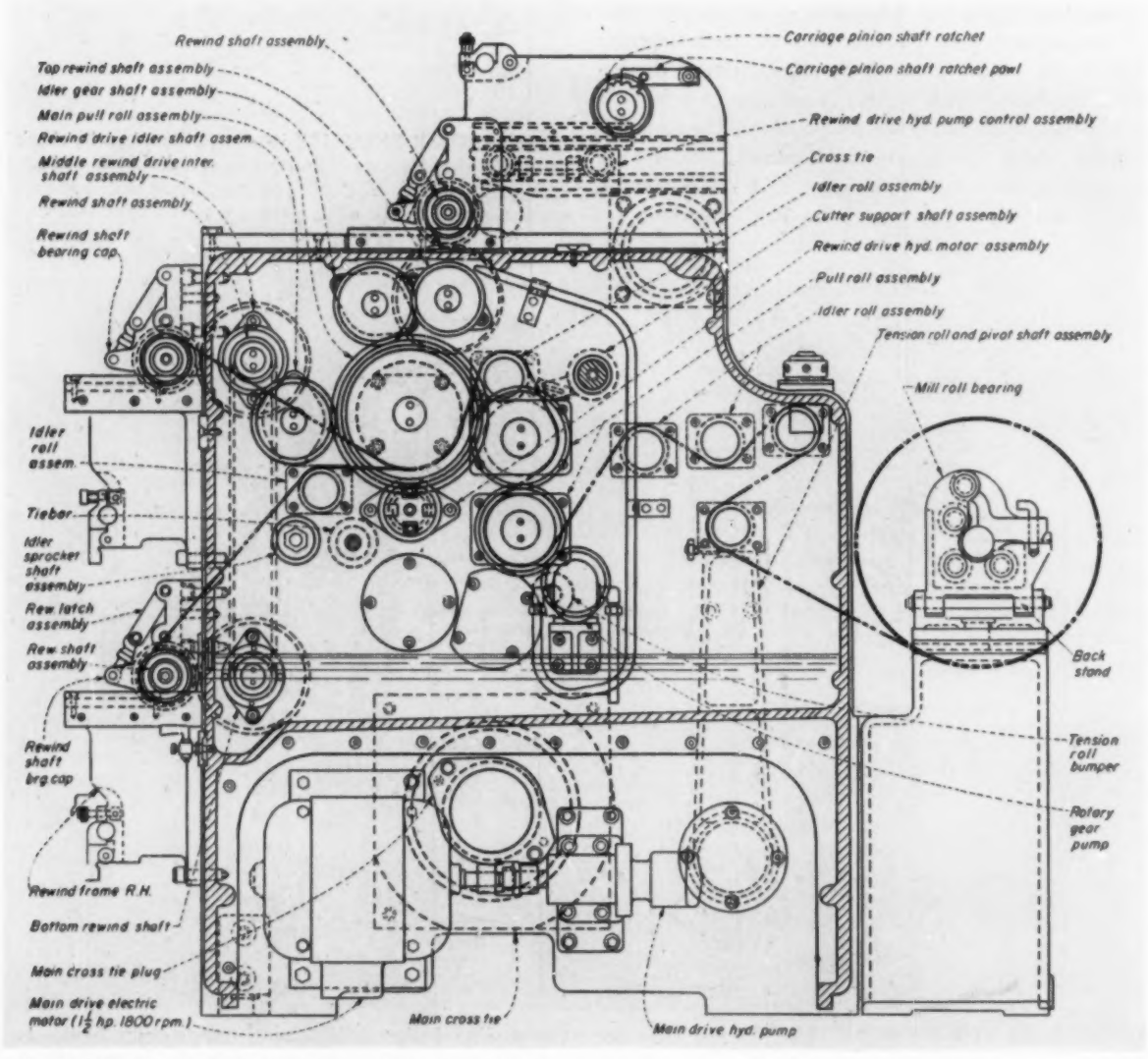


TO RELEASE THE PARKING BRAKE first close the main line switch. A full application of the control cylinder foot-pedal compresses the brake setting-spring. The limit switch closes an electric circuit which energizes the magnetic check valve and illuminates the signal light. The check valve traps the fluid in the releasing cylinder and holds the parking brake setting-spring compressed. Now, the service brake is applied by pressure on the foot-pedal. To park the crane, press the pushbutton to open the electric control circuit. The check-valve releases the trapped fluid and allows the parking brake to set by spring action. The brake is applied when the main line switch is opened.

High-Speed Slitter-Rewinder Uses

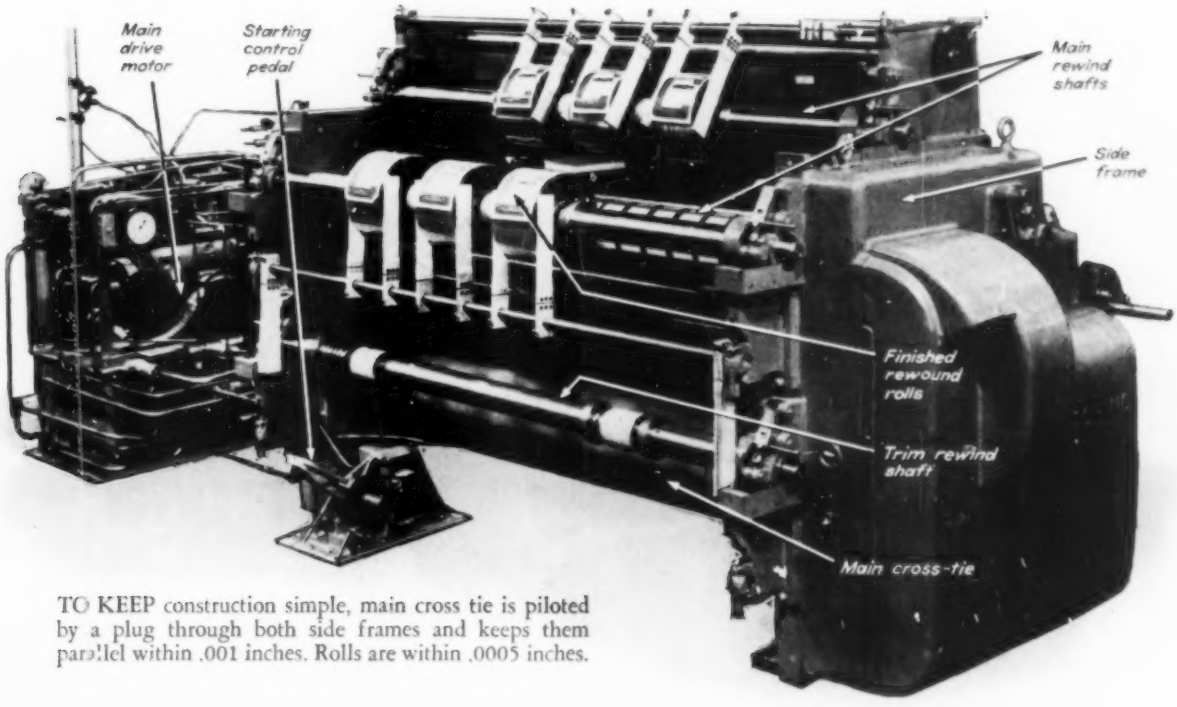
Equipped with a variable speed hydraulic main drive and a separate, but positively interlocked, variable speed hydraulic rewind drive, this machine is the first all-hydraulic slitter-rewinder ever made. Rewind speeds up to 1,000 ft. per minute are possible with rewound rolls up to 15 in. in diameter. Razor blade slitting permits strip widths as narrow as $\frac{1}{2}$ in. and three differential center-rewind shafts provide for positive roll separation and trim salvage.

The Cameron Machine Co. of Brooklyn, New York, developed this Triplex Machine for high speed slitting and rewinding of Lumarith, a transparent plastic film product. Besides being simple, economical, and rugged, the Triplex provides sensitive web tension control and uniformly dense rewound rolls, regardless of thickness variations in the parent roll. Differential rewinding is used to minimize the heat generated by friction between the core and rewind shaft and thus prevent damage to the inner laps of the rewound rolls. Several rolls of different sizes can be rewound at the same time.

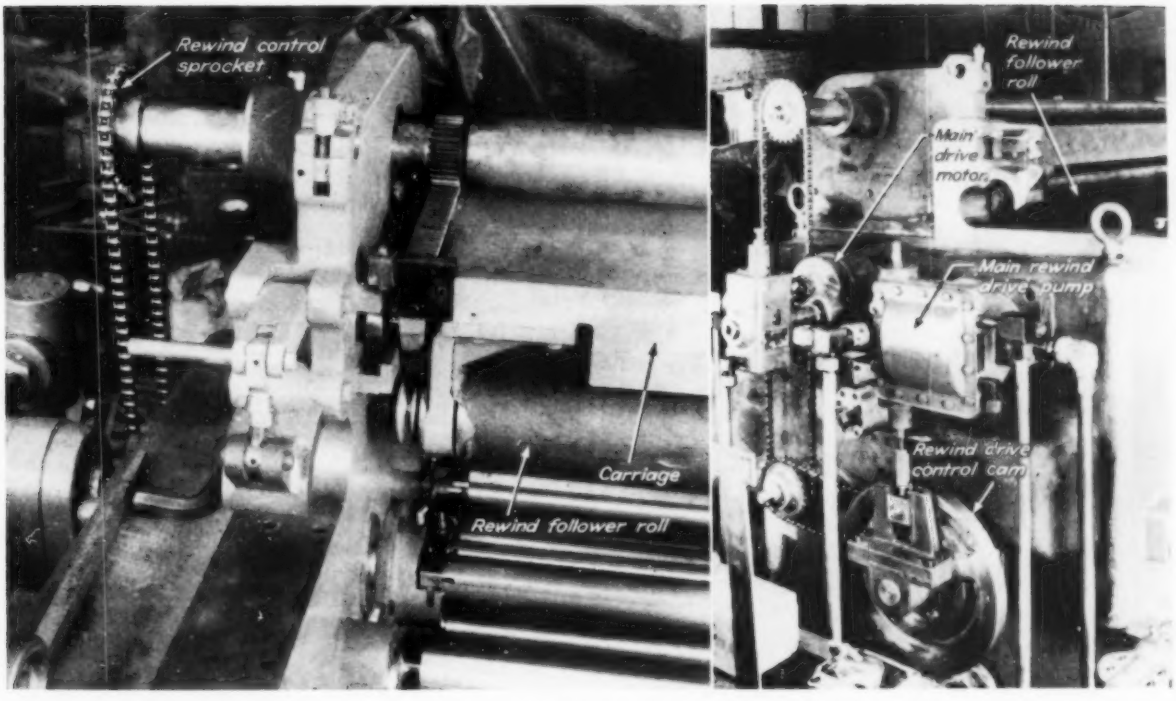


DIFFERENTIAL REWINDING uses single rewind shaft speed despite differences in diameter of rewound rolls caused by thickness variations in parent roll. Material is wound on cores separated by spacers and washers. Washers are keyed to rewind shafts; cores and spaces are not. Axial spring pressure allows transmission of torque from washers to cores but permits cores to slip as required by the differences in diameters of the rolls that are being rewound.

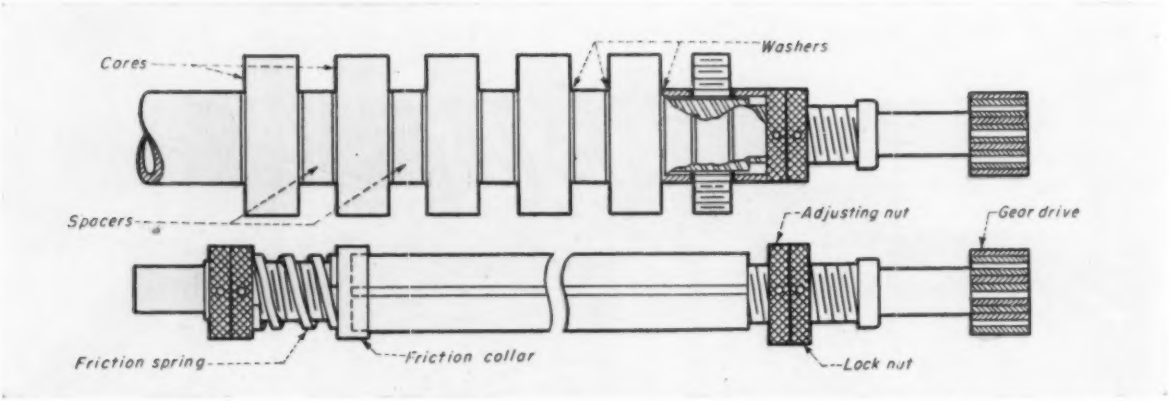
All Hydraulically Driven Rollers



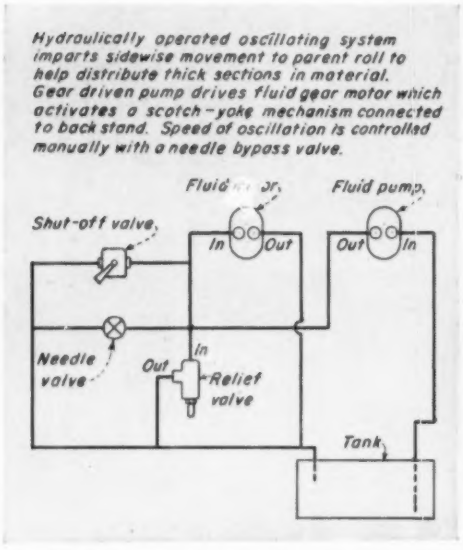
TO KEEP construction simple, main cross tie is piloted by a plug through both side frames and keeps them parallel within .001 inches. Rolls are within .0005 inches.



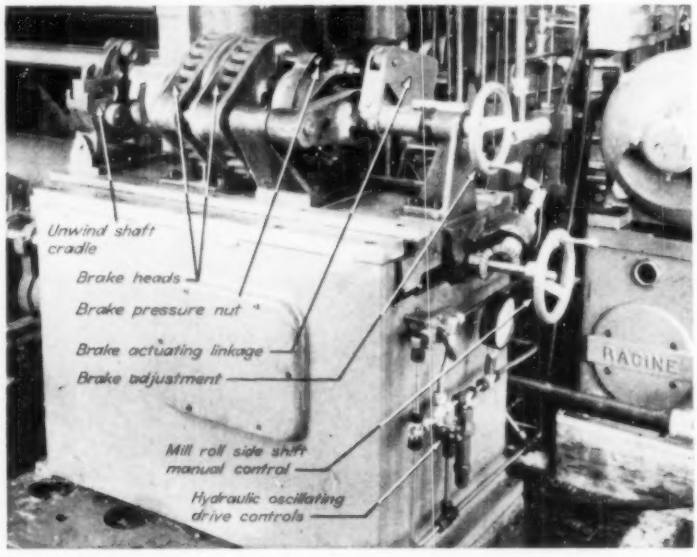
SPEED OF REWINDING shafts is varied inversely with diameter of rewound rolls to keep slip, and heat generated by slipping, from getting excessive as rewound rolls increase in size. As roll dia increases, rewind follower roll, which beares on outside dia of rewound roll, moves carriage forward, rotating rewind control sprocket through rack and pinion. Sprocket driven chain regulates rewind shaft speed by adjusting the pump stem and yoke of the main pump.



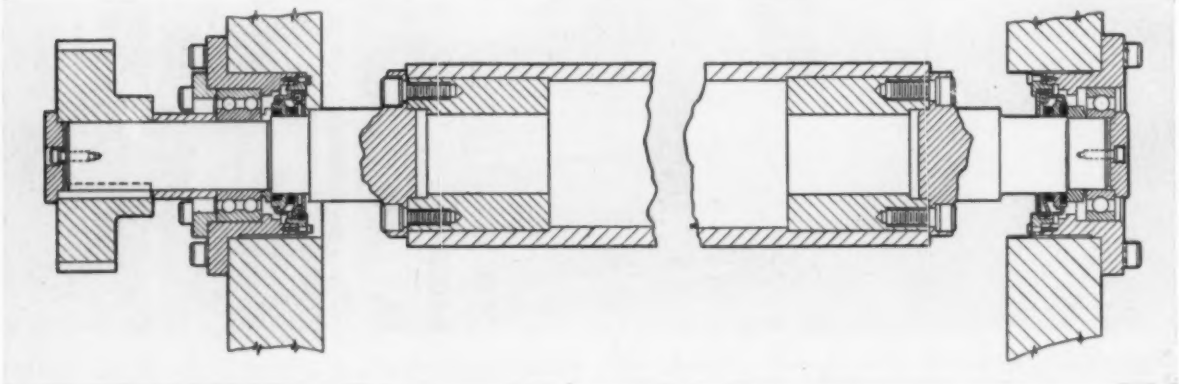
MATERIAL IS STRIPPED from mill or parent roll by three pull rolls which are driven by the main drive fluid motor through a gear train. Rewind shafts, driven by a separate fluid motor, rewinds strips after they have been cut into the desired widths. The horizontal rolls are held parallel within 0.0005 inches by rigid mountings. All gears except the three rewind pinions and their mating gears run in oil. Gears for rewind rolls have no positive lubrication.


Hydraulically operated oscillating system imparts sidewise movement to parent roll to help distribute thick sections in material. Gear driven pump drives fluid gear motor which activates a scotch-yoke mechanism connected to back stand. Speed of oscillation is controlled manually with a needle bypass valve.
Fluid motor
Fluid pump
Shut-off valve
In
Out
Out
In
Needle valve
Out
In
Relief valve
Tank

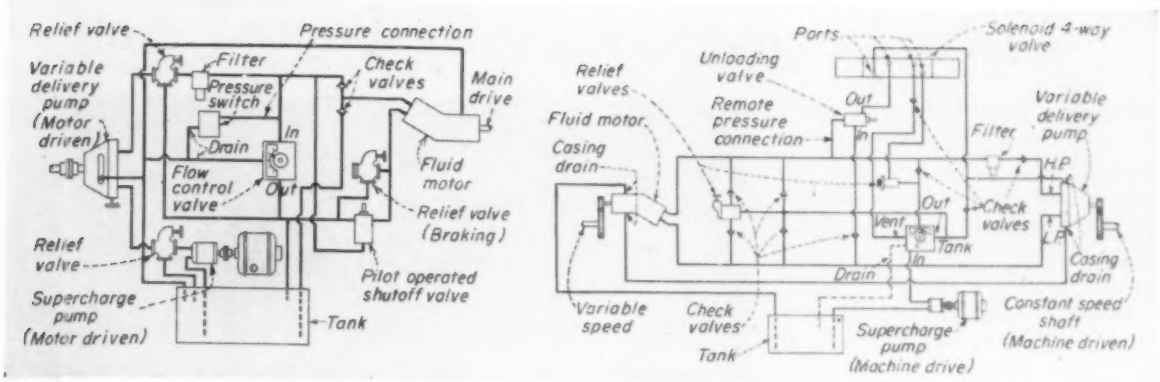
HYDRAULICALLY operated oscillating system



TENSION CONTROL ROLL is counter weighted to keep tension in

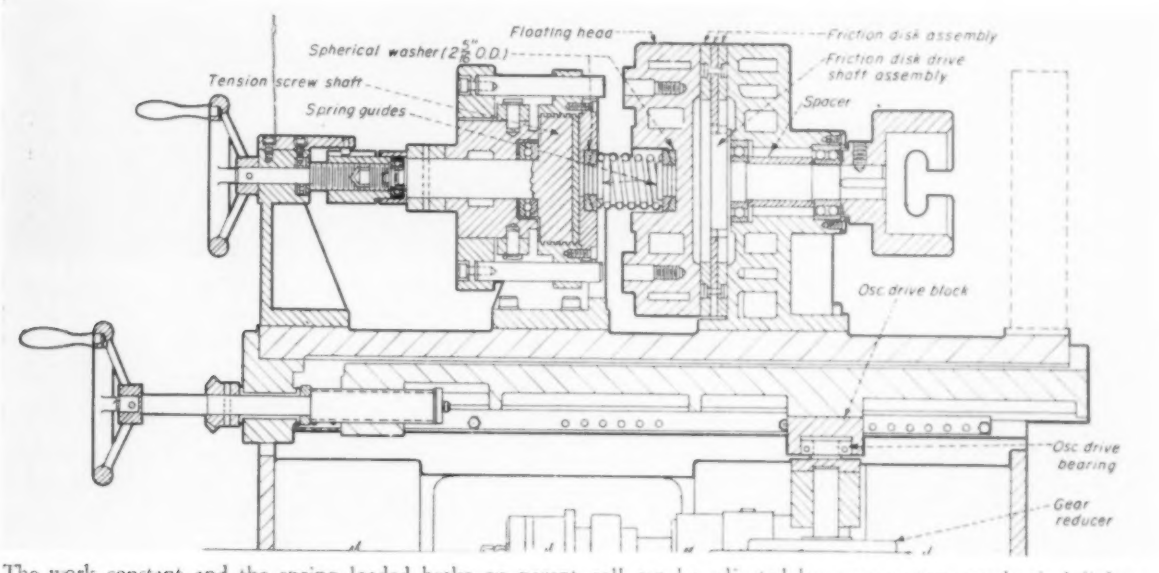


PRELOADED DOUBLE ROW ball bearings on pull roll (left) eliminates end play of shaft. Rewind shafts (right) are mounted in meter changeable cartridges made of similar bearings, and provided with side plates to prevent end play.

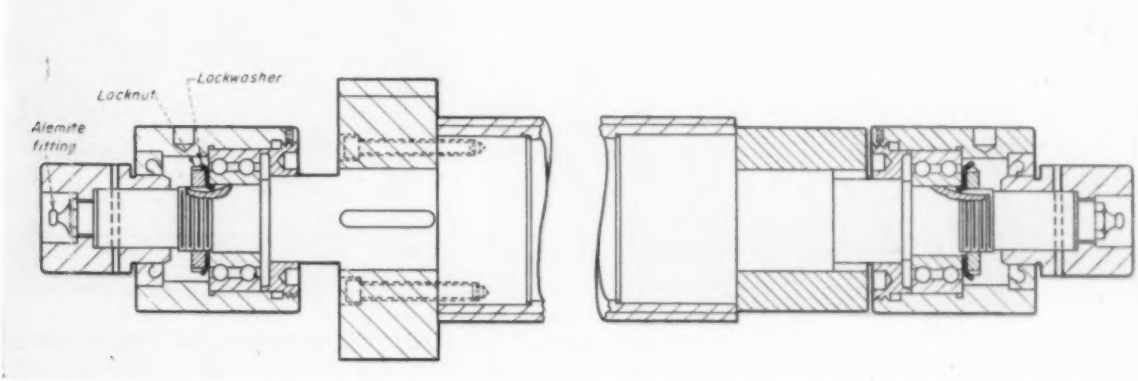


MAIN DRIVE ELECTRIC MOTOR powers a low pressure, vane-type supercharging pump and the variable delivery, main drive hydraulic pump. Supercharge pump maintains sufficient suction pressure to prevent cavitation.

VARIABLE DELIVERY PUMP of the rewind system is driven at constant speed. Supercharge pump prevents cavitation, supplies low pressure oil for cooling motors, and provides make-up oil in the rewind hydraulic system.



The work constant and the spring loaded brake on parent roll can be adjusted by a screw type mechanical linkage.

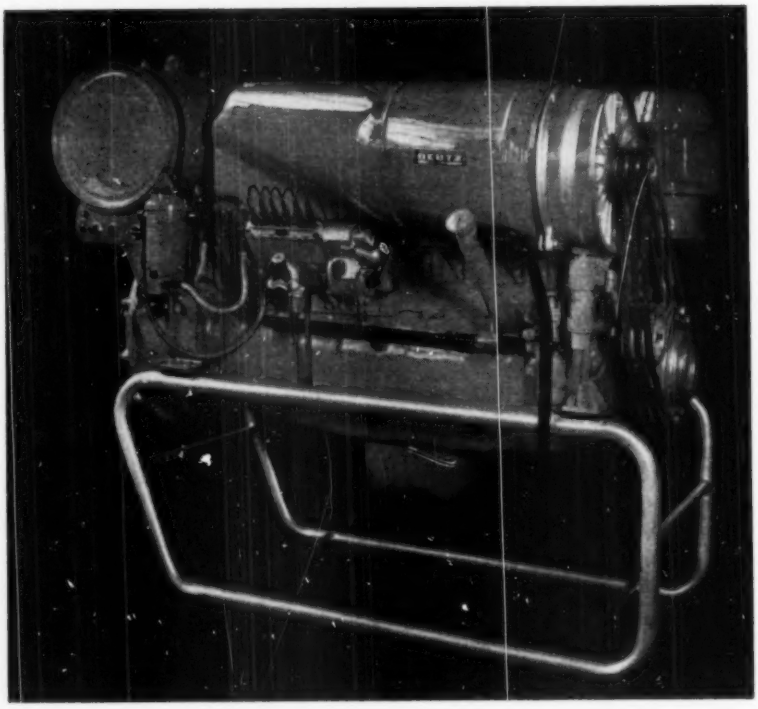


Using shims with cartridges makes rewind shafts interchangeable. The exposed rewind pinions are keyed to their shafts and held in place counter sunk allen head cap screws. Grease fittings provide convenient lubrication.

Diesel Engine Cooled by Forced Air

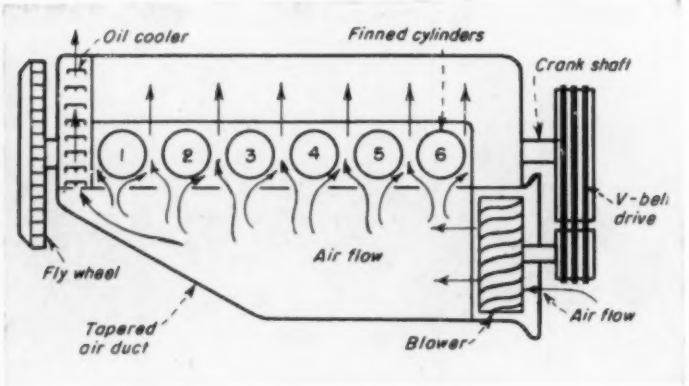
An axial flow vane type blower, tapered air duct and guide plates attached to finned cylinders insure satisfactory air distribution to the cylinders of the Deutz in line air cooled diesel engine. This air cooling system together with a built in oil cooler maintains normal engine operating temperatures. The advantages gained in an engine using such an air induction cooling system over a watered cooled engine of similar size and capacity are reduced weight, greater simplicity and reliability and better thermal efficiency. The radiator, water jacket, circulating pump, rubber connections and thermostats used on a liquid engine are not necessary. There are no coolent evaporation or freezing problems and operating temperatures of 200 C can be safely maintained.

The cylinder heads are provided with a pear shaped turbulence chamber which helps in accomplishing a through mixture of the compressed air and fuel. The chambers are located on the sides of the cylinders and inclined at 30 deg to accommodate large valves necessary for high volumetric efficiency. These engines are manufactured at Kloeckner-Humbolt Deutz A.G., Cologne, Rhine.

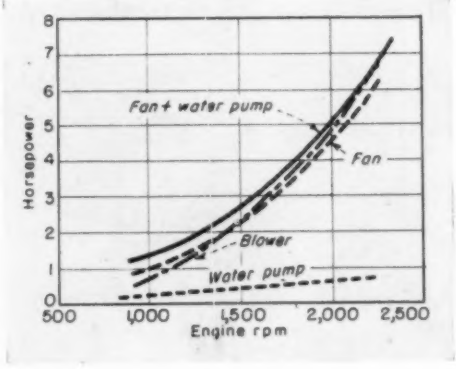


ON THE A6L514 MODEL ENGINE the blower is driven at a speed of 6,000 to 8,000 rpm by a multi V-belt drive from a pulley in the crank shaft. Belt tension is maintained by an idler pulley mounted on a spring and hydraulically operated bracket. To the right rear is the combustion air intake. At top center is the tapered air duct below the left end of which is located the Bosch injection pump. With reversing gear this 6 cylinder engine weighs 1,975 pounds.

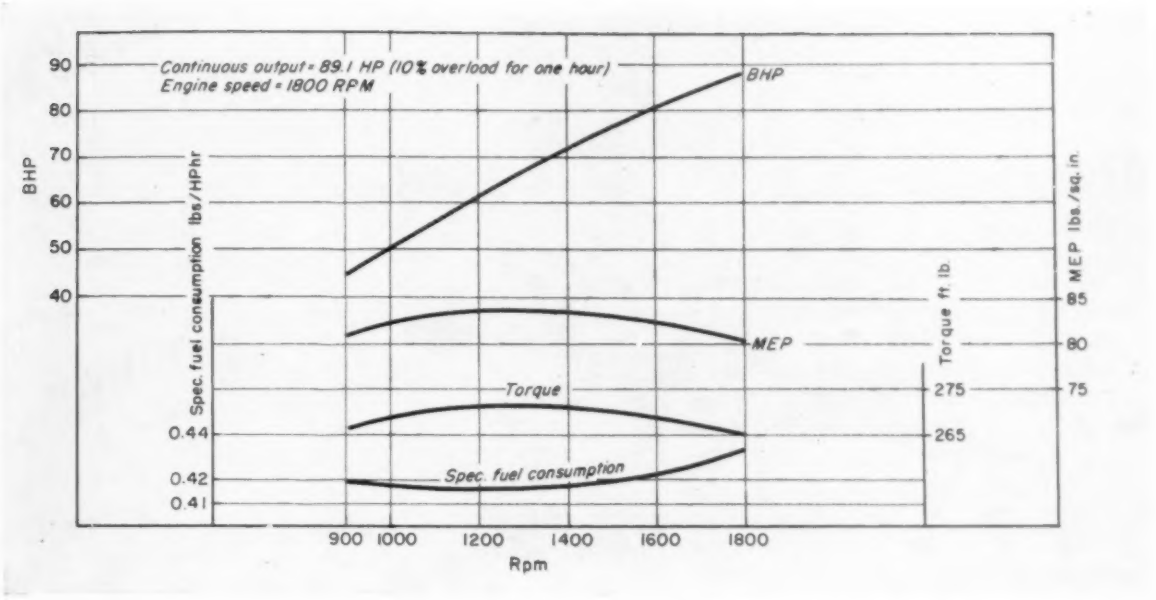
A complete line of these engines is being manufactured for service in all types of marine mobile and construction equipment. It is claimed that they will operate in temperatures from —40 to +140 F.



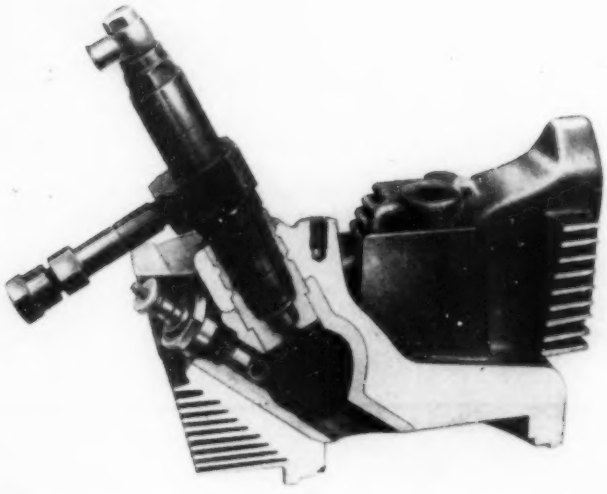
FLOW OF COOLING AIR through engine. At maximum load, a volume of 230,000 cu ft per hr of air is required for cooling the engine at normal atmospheric conditions. The pressure produced in the tapered duct by the blower is about 55.3 lb per sq ft. Speed of the blower is about three times the speed of the engine.



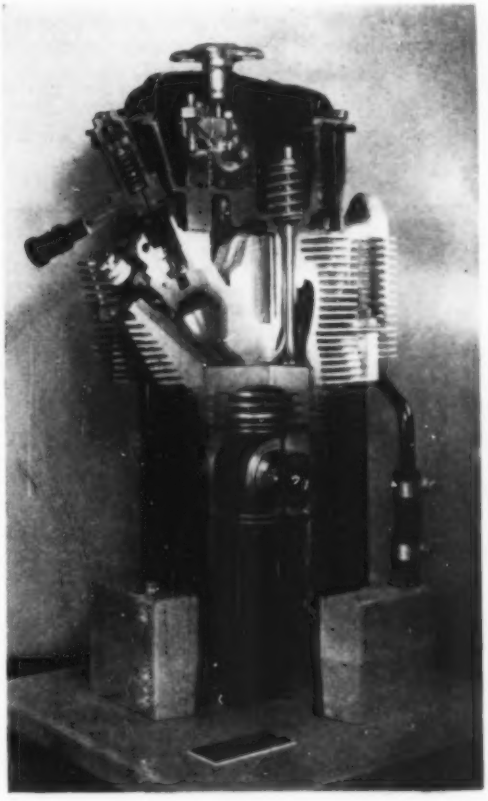
POWER REQUIRED to drive the blower of the Deutz air cooled engine compared with power required to drive the water pump and radiator cooling fan of a water cooled engine of equal power. Power consumed is about equal.



PERFORMANCE DATA of the Deutz A6L514 engine. Six cylinders, bore 4.33 in. stroke 5.51 in., swept volume 486.96 cu in. compression ratio 17.3 to 1. Speed and power recommendations are 60 hp at 1,200 rpm and 75 hp at 1,500 rpm with a minimum fuel consumption at 0.41 lb bhp hour.



PEAR-SHAPED SWIRL CHAMBER comprises about 60 percent of the total compression space of the cylinder. It is made of cast iron and is cast into the aluminum head. The main portion of fuel spray is directed towards the throat with only a small portion striking the walls. The heater plug below the injector is used for starting the engine in temperatures below freezing. The chamber injection and heater plugs are situated at the edge of the cylinder to accommodate large valves and to be cooled directly by the blower.

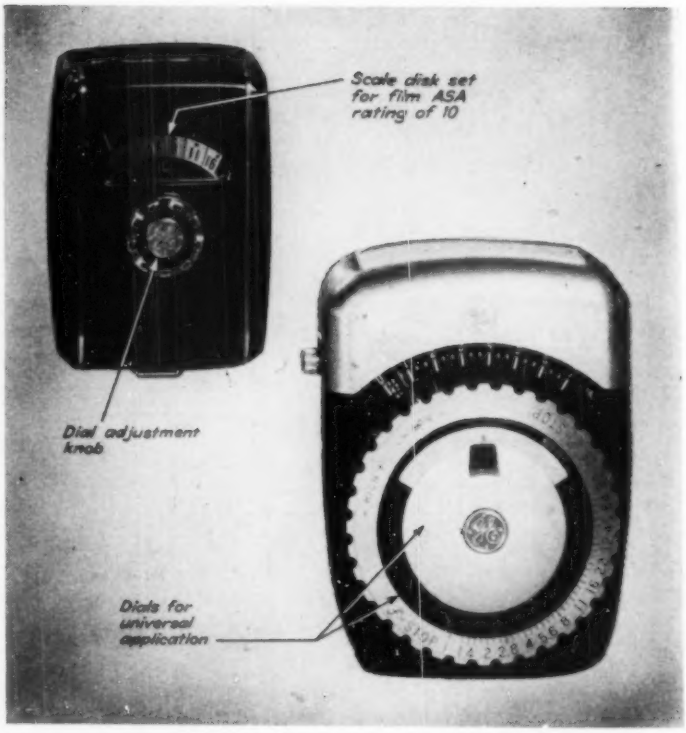


MACHINED CIRCULAR FINS of the removable cylinder barrel extend over the full length of the piston stroke. It is tightly fitted into the die cast aluminum alloy cylinder head to keep cylinder head and cylinder together as a unit during service assembly and disassembly and prevent damage to the head gasket. The flat domed aluminum-silicon piston is provided with three compression rings and two oil rings. To facilitate molding and casting, the valve gear box is a separate cast iron part bolted to the cylinder head. A stamped sheet metal cover protects rocker gear. All valve guides are cast iron.

Midget Exposure Meter

The "Mascot" direct reading exposure meter, developed by the Meter and Instrument Department of the General Electric Company, is a simplified, small size meter designed specifically for amateur photographers, color slide photographers and home movie makers. Compactness and simplicity were obtained by making the meter responsive only to reflected light, by eliminating complicated conversion scales, by using a small germanium photocell and a unique inside and out magnet construction.

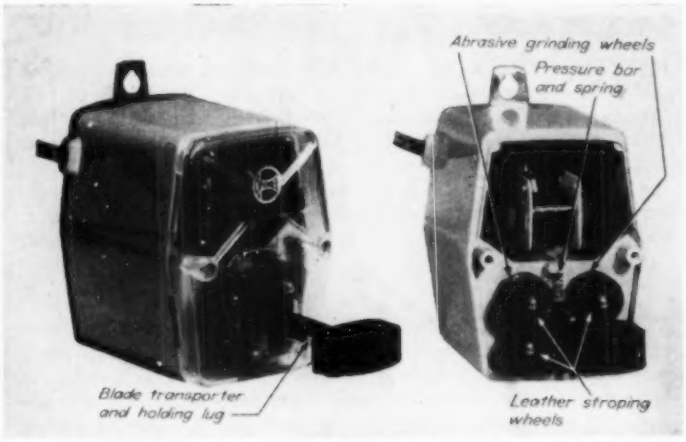
There is a direct reading scale marked in f-numbers so the pointer instantly shows the correct setting for a camera shutter speed of 1/25 of a second. Four rotating scales inside the case are marked for a popular type of film (5, 10, 16, 50 ASA). These four scales cover the requirements for most photographers. A calculator is provided with the Mascot that can be used to convert direct reading to lens openings where the meter does not satisfy the photographic conditions encountered or camera shutter speed used.



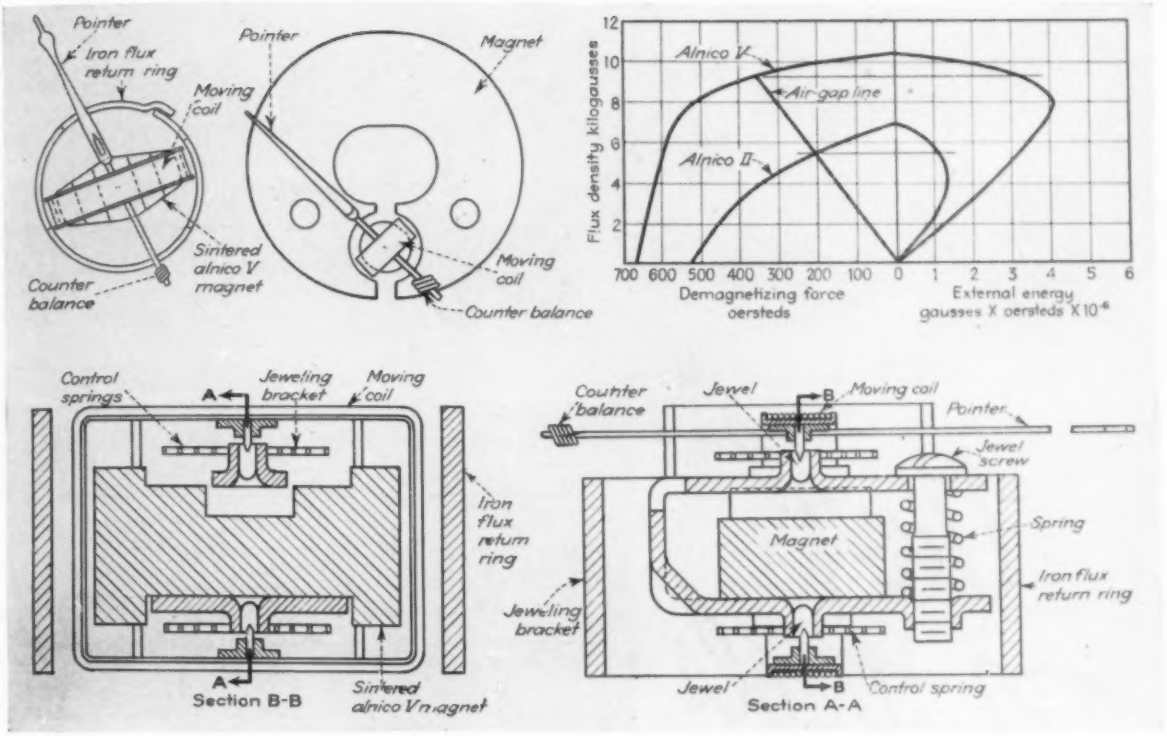
THE MASCOT, left, is 1 11/16 long, 2 3/8 wide, 15/16 thick and weighs 2½ ounces while the more versatile professional meter, right, is much larger and complex. The single adjustment knob is mounted through the cotton-flock-filled phenol case and attached to the scale disk. On the disk are printed four scales graduated in camera lens F numbers and corresponding ASA film speed ratings. When the desired scale is turned into position, the disk is locked in place by a snap type ball detent lock. If the voltaic light cell mounted in the top of the case is pointed towards the scene to be photographed, the pointer will swing to the camera lens F number for the exposed film.

Worm Drive Used On Blade Sharpener

This electrically operated razor blade sharpener, for honing and stroping double edged razor blades, uses a twin gear worm drive to transmit power from its electric motor to the four shafts on which the honing and stroping wheels are mounted. When the blade transporter is pulled from closed position, the points of the electric switch make contact and the motor and grinding wheels start turning. It is being made by the Dremel Manufacturing Company, Racine, Wis.

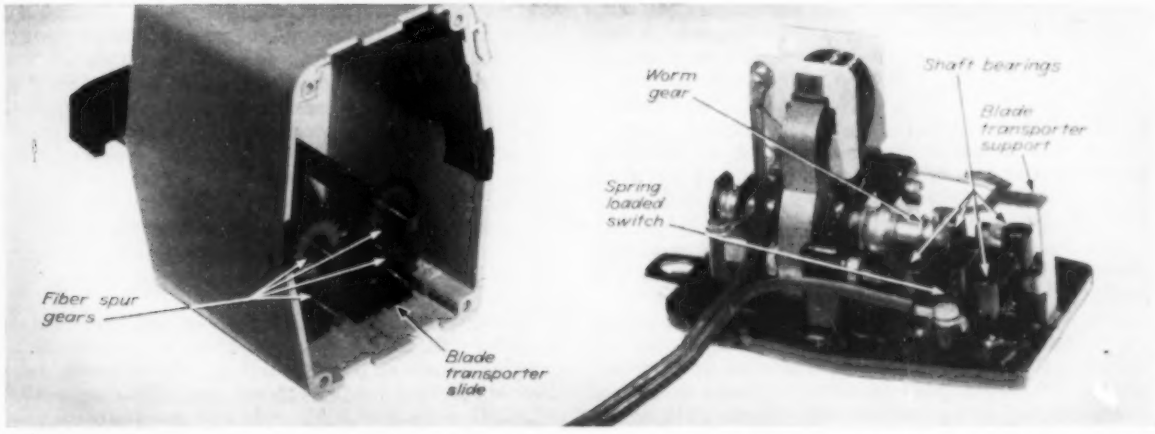


PLASTIC CASE is 2½ in. wide, 3¼ in. high, 3¼ in. long. Upper shafts are spring loaded to insure contact between the wheels and the razor blade during the sharpening and stropping process.



COMPARISON OF THE MASCOT POINTER deflection meter assembly with that of the PR 1. The Sintered Alnico V magnet of the Mascot meter at upper left, is mounted inside the deflection coil. The outer ring mounted around the deflection coil of the Mascot deflects miscellaneous magnetic flux back into the meter field. This ring helps maintain sensitivity of the meter and minimizes the amount of escaping magnetic flux that will effect other instruments in close proximity. On the PR 1 the deflection coil is mounted inside the permanent magnet.

BEARING MOUNTING and adjustment assembly. By turning the jewel screw the bearing pressure between the needle points and the jewels is simultaneously adjusted on both bearings. The pressure spring maintains the adjustment. The magnet is mounted to the jewel bracket and the jewel bracket and flux return ring are mounted to the case. Because of its greater flux density Alnico V magnet material is used to reduce the size of the permanent magnet without sacrificing meter sensitivity. The graph at upper right shows magnetic characteristic of Almico V and Almico II.



ONLY THE TWO TOP GEARS MESH with the worm gear. The worm gear is mounted on the shaft of a 110-120 v a-c d-c motor. The blade being sharpened rides on the lug of the transporter slide. When the blade transporter is pulled from the spring type switch, the points make contact and the motor starts. Bearing bosses are molded on plate.

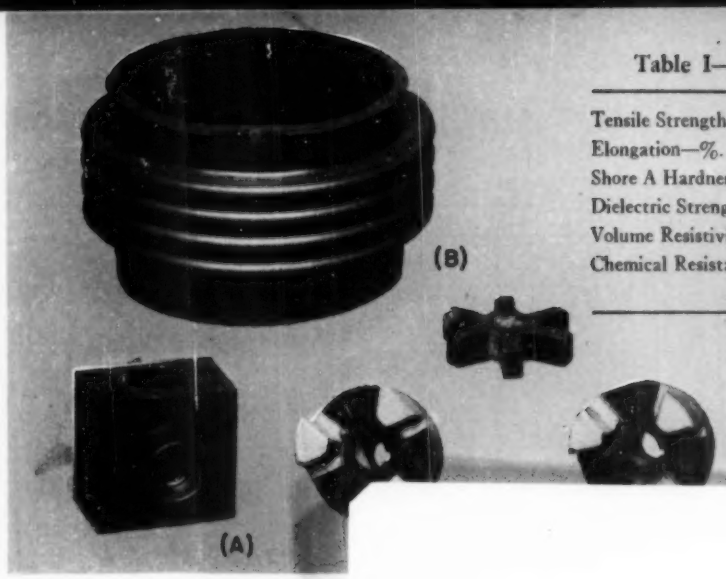


Table I—Property Range of Cured Vinyl Plastisols

Tensile Strength psi	1500–4000
Elongation—%	150–500
Shore A Hardness	30–95
Dielectric Strength (volts/mil)	200–500
Volume Resistivity (OHMS/CM)	25–6.0 x10⁹
Chemical Resistance	Good in acids, bases, alcohols Poor in ketone and ester solvents

Fig. 1—Small valve (A) used in the assembly of a special soil testing apparatus. Ports enter the valve in various directions, providing connections between vacuum pumps and filtering chambers. This unit is comprised of a one-piece casting of vinyl plastisol. The bellows-shaped casting (B)

Vinyl Plastis

JOHN DELMC
Consulting Engi

VINYL RESIN PLASTISOLS have recei
finished components for various
The major advantage of these m
other plastics is the simplicity w
converted into finished products.
critical curing schedules of natu
components, a simple heat gelatio

The vinyl plastisols consist of
resins dispersed in a phase of liq
lizer. There are no volatile const
dispersions. The plastisol can be
applied as a coating by dipping.
applied, gelation will take place
solubilized by the plasticizer.

The cured product or coating ra
like consistency to a firm texture.
Table I, which make vinyl plastis
gineering applications are:

(1) Good dielectric qualities.
permanent than those encounter
goods, which tend to deteriorate v

(2) Resistance to oils and ch
are resistant to most acids and a
oxidizing acids such as chromic
plating. In general, good resistar
greases, alcohol and petroleum b
tones, tetrahydrofuran and dimeth
swelling or exert a partial solve
may be used to advantage in sel

(3) Good abrasion resistance.

BOOK E
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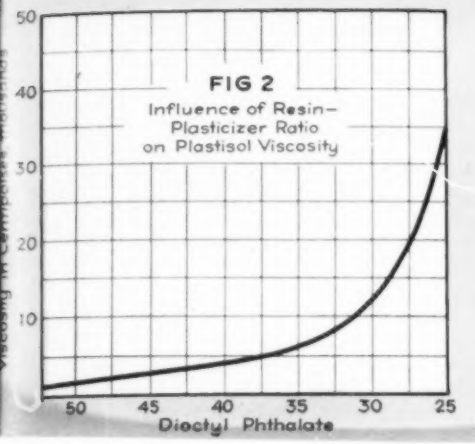


FIG 2
Influence of Resin–Plasticizer Ratio on Plastisol Viscosity

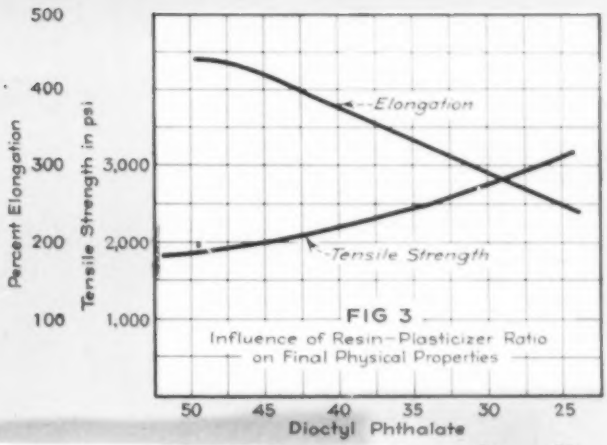
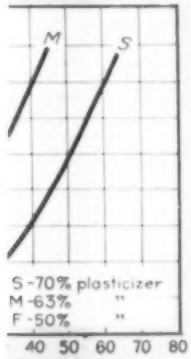


FIG 3
Influence of Resin–Plasticizer Ratio on Final Physical Properties



nyl Plastisols

BOUND

GHTLY

l plastisol molds of an
he added advantage of

ɔcen shaped into solid
l, the technique of slush
ts of pouring the liquid
is rotated. Gelation is
ɔrm a thick surface skin.
ed out and the hollow
also found some appli-
kets.

alysis

mportant applications as
ɔecause of the ease with
ɔns may be shaped and
dvantages of vinyl com-
ns will exemplify those
ɔear to best advantage.
gs from vinyl plastisols
ısequently heavy deposits
These coatings are not
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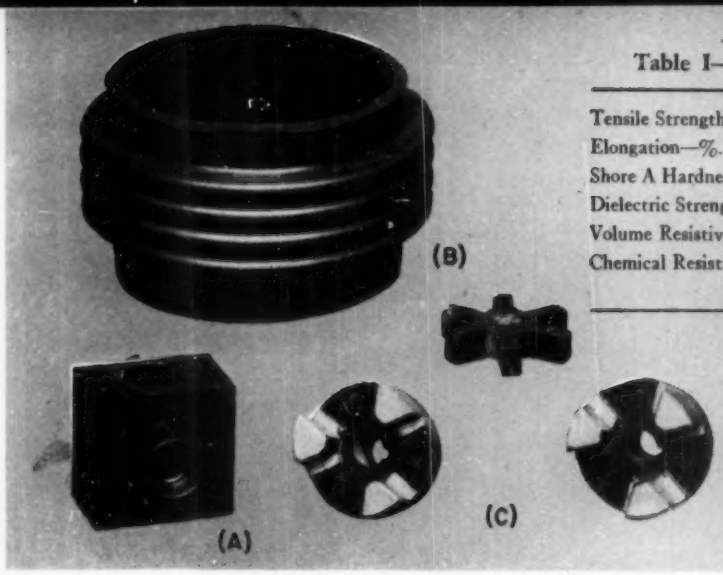

Table I—Property Range of Cured Vinyl Plastisols

Tensile Strength psi	1500–4000
Elongation—%	150–500
Shore A Hardness	30–95
Dielectric Strength (volts/mil)	200–500
Volume Resistivity (OHMS/CM)	.25–6.0×10⁹
Chemical Resistance	Good in acids, bases, alcohols Poor in ketone and ester solvents

Fig. 1—Small valve (A) used in the assembly of a special soil testing apparatus. Ports enter the valve in various directions, providing connections between vacuum pumps and filtering chambers. This unit is comprised of a one-piece casting of vinyl plastisol. The bellows-shaped casting (B) and the star-shaped machine drive component (C) are prepared from vinyl plastisols.

Vinyl Plastisols

JOHN DELMONTE
Consulting Engineer

Table II—Vinyl Resins Used in Plastisol and Organosol Formulations

Resin	Trade Designation	Typical Source
Polyvinyl Chloride	"Geon" 100 Series "Marvinol" VR-10 "Pliovic" A	B. F. Goodrich Chem. Co. Naugatuck Chem. Co. Goodyear Tire and Rubber Co.
Copolymer polyvinyl chloride-acetate	Vinylite VYNV	Bakelite Corp.
Copolymer polyvinyl chloride-vinylidene chloride	"Geon" 200 Series	B. F. Goodrich Chem. Co.

VINYL RESIN PLASTISOLS have recently been used to produce finished components for various machines and products. The major advantage of these materials over rubber and other plastics is the simplicity with which they can be converted into finished products. Unlike the relatively critical curing schedules of natural or synthetic rubber components, a simple heat gelation is all that is required.

The vinyl plastisols consist of finely divided polyvinyl resins dispersed in a phase of liquid plasticizer and stabilizer. There are no volatile constituents present in these dispersions. The plastisol can be poured into a mold or applied as a coating by dipping. When adequate heat is applied, gelation will take place as the vinyl plastic is solubilized by the plasticizer.

The cured product or coating ranges from a soft, rubber-like consistency to a firm texture. Some of the properties, Table I, which make vinyl plastisols useful for many engineering applications are:

(1) Good dielectric qualities. These properties are more permanent than those encountered with natural rubber goods, which tend to deteriorate with age.

(2) Resistance to oils and chemicals. Vinyl plastisols are resistant to most acids and alkalies, including strong oxidizing acids such as chromic acid used in chromium plating. In general, good resistance is offered to oils and greases, alcohol and petroleum base solvents. Higher ketones, tetrahydrofuran and dimethyl formamide may cause swelling or exert a partial solvent action. This property may be used to advantage in selecting solvent adhesives.

(3) Good abrasion resistance.

(4) Permanence of properties. The vinyl plastisols retain their physical and electrical properties over long periods.

(5) Good colorability. The colors obtainable with the plastisols are durable and may be processed to many shades.

(6) Good shock absorbing qualities.

The load-deformation characteristics of several typical grades of vinyl plastisols are brought out in Fig. 5. Their behavior differs widely at the two temperatures selected for test purposes. The degree of property variation will depend upon the amount and nature of plasticizer content. A fact frequently overlooked is the magnitude of creep that will take place under sustained loads. Short-time creep results under a constant stress of 300 psi indicate that the compounds possessing the greatest elastic deformation also creep to a greater extent. In general, for a given formulation, those compounds prepared with larger amounts of plasticizer will creep at a faster rate. Usually the recovery from deformation is not as rapid as for competitive rubber compounds.

Casting of Liquid Plastisols

The properties of vinyl plastisols as uncured liquids or as gelled solids are largely a function of resin-plasticizer ratio as shown in Figs. 2 and 3. The viscosity varies from about 500 centipoises to stiff, non-mobile pastes. The plastisols are usually stable over long periods of time, although heating will produce some gelation. In Fig. 4 the viscosity characteristics are shown over a range of temperatures. The initial heating may effect a light reduction in viscosity due to the greater fluidity of the plasticizer.

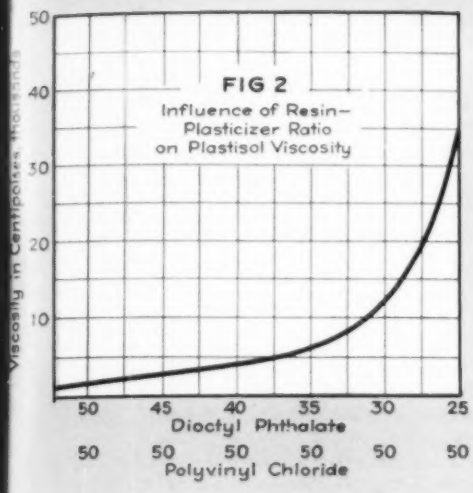

FIG 2 Influence of Resin–Plasticizer Ratio on Plastisol Viscosity

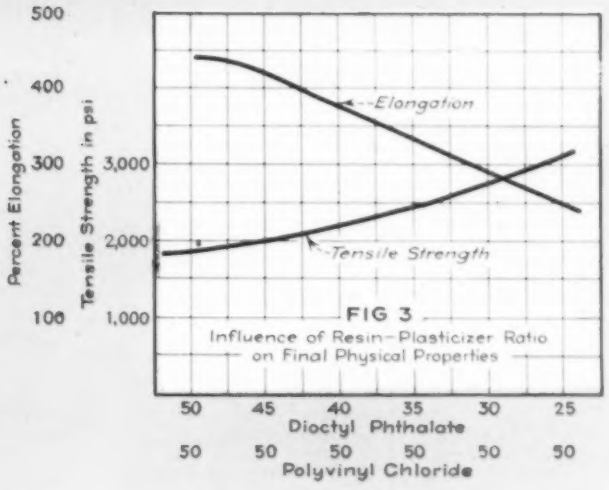

FIG 3 Influence of Resin–Plasticizer Ratio on Final Physical Properties

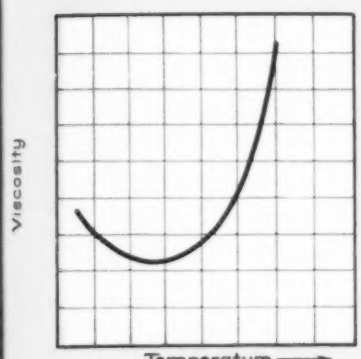

FIG 4 Increase of Plastisol Viscosity on Heating

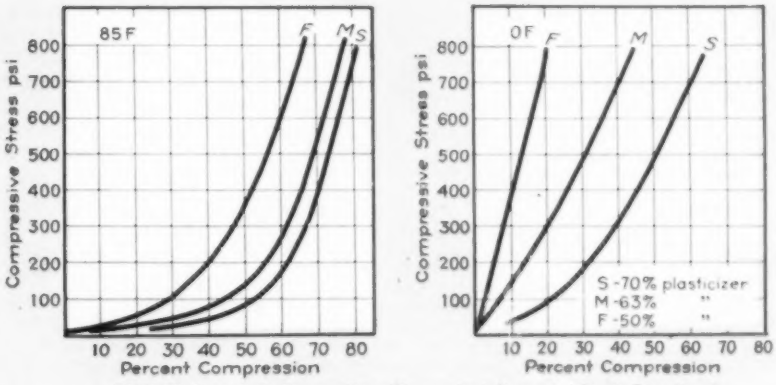

FIG 5 Load Deformation Characteristics of Vinyl Plastisols

However, this is followed by an increase until gelation occurs. Since gelation is a function of time and temperature, it may be produced at lower temperatures with slower rates of heating.

The casting of liquid vinyl plastisols is a simple procedure. The material is poured into molds. Entrapped air bubbles are allowed to rise to the surface before the parts are subjected to an elevated temperature. For complicated components with convolutions and undercuts, the filled molds should be exposed to vacuum before heating. Paste-like formulations are best handled in completely enclosed molds. Positive pressure can be applied to insure complete distribution of the plastisol and to effect complete removal of air bubbles.

Gelation temperatures of 340 to 350 F are recommended for most plastisols. There are some, however, that may be gelled at temperatures as low as 210 F.

The time to achieve satisfactory gelation will depend upon the thermal diffusion within the vinyl plastisol and the rapidity with which the mold attains the gelation temperature. If short-lived gypsum molds are used, the gelling process may require several hours. Metal molds will produce a faster cure—approximately 5 to 10 minutes for each $\frac{1}{4}$ inch of thickness. Gelling will proceed from the mold walls to the center of the casting.

Cured parts may be taken from the mold while hot, but if severe undercuts are present, the plastisol will tear. It is best to allow sufficient cooling to permit removal of parts without damage.

Some grades of low temperature curing plastisols can be cast in previously formed vinyl plastisol molds of an identical composition. This has the added advantage of easy removal of cured parts.

Not all vinyl plastisols have been shaped into solid castings. In the toy and novelty field, the technique of slush molding has been used. This consists of pouring the liquid plastisol into a heated mold that is rotated. Gelation is allowed to proceed sufficiently to form a thick surface skin. The ungelled portion is then poured out and the hollow casting removed. This process has also found some application in the molding of small buckets.

Application Analysis

Vinyl plastisols will find many important applications as machine and product components because of the ease with which their rubber-like formulations may be shaped and because of the inherent property advantages of vinyl compounds. The following applications will exemplify those instances where vinyl plastisols appear to best advantage.

1. Protective Coatings: Coatings from vinyl plastisols contain no volatile solvents and consequently heavy deposits can be made in one application. These coatings are not subject to the volumetric shrinkage of lacquers.

The usual procedure for applying a coating is to heat the parts to be coated to the temperature of gelation, or slightly higher, and then immerse them in the vinyl plastisol. There will be an immediate gelation of the coating on the surfaces of the part. This is followed by a reheating at about 350 F to complete the cure of the coating. Additional layers may be applied by the same procedure. Coating

Table III—Representative Plasticizers for Vinyl Formulations

Chemical Composition	Properties Developed
PHOSPHATED ESTERS	
Tricresyl Phosphate Triphenyl Phosphate	Imparts non-flammable qualities, though has poor low temperature characteristics
Trioctyl Phosphate Octyl diphenyl phosphate	Improved flexibility at low temperatures
PHTHALATED ESTERS	
Dioctyl Phthalate Di-2-ethyl hexyl phthalate	Most widely used general purpose primary plasticizer for vinyls. Used in conjunction with other plasticizers
Butyl Benzyl Phthalate Di-capryl phthalate Di-butoxyethyl phthalate	General purpose primary plasticizers Fair low temperature properties
ADIPATE, SEBACATE, AND AZELATE ESTERS	
Dioctyl Sebacate Dioctyl Adipate Dihexyl Sebacate Dihexyl Azelate Dicapryl Adipate	Excellent low temperature flexibility (Brittle point less than −70° F) Higher in cost than other plasticizers
RESINOUS COMPOUNDS	
Ethylene glycol-alkyd resins Diallyl phthalate polyesters Acrylonitrile-butadiene copolymers	Low volatility, permanence, low extractability (not fluid enough for plastisol formulations)
MISCELLANEOUS	
Oleated and Ricinoleated Esters	Secondary plasticizers, low temperature flexibility, only fair chemical resistance
Chlorinated Paraffins	Low cost secondary plasticizer to enhance flameproof qualities
Petroleum Derivatives	Numerous aromatic compounds aiding plasticization of the vinyl

Table IV—Typical Stabilizers for Vinyl Resin Compounds

Chemical Composition	Properties Developed
ALKALI METAL SALTS	
Sodium alkyl phosphates	Decided gain in light stability Limited heat stability
ALKALINE EARTH METAL SALTS	
Barium Ricinoleate	Heat stability for transparent and opaque formulations. Used in conjunction with cadmium stabilizers
Calcium stearate	Fair heat stabilizer for non-toxic applications. Offers lubricating qualities
Strontium Naphthenate	Good light stability—used in conjunction with other stabilizers
HEAVY METAL SALTS	
Basic Lead Carbonate	Good electrical and heat stabilization
Dibasic lead phosphite Dibasic lead phthalate	Good sunlight and heat stability
Lead Stearate	Heat stabilizers and lubricants
Cadmium Ricinoleate Cadmium 2-ethyl hexoate	Heat stabilizers in clear compounds Prevent color formation
Organic tin stabilizer	Excellent for producing clear films with heat and light stability. Non-toxic.
SPECIAL COMPOUNDS	
Epoxy resins	Useful with formulations involving chlorinated plasticizers

thickness will depend upon the viscosity of the plastisol and on the heat capacity of the part being coated.

Parts such as tool handles, wire racks, and various subassemblies can be handled on a semi-automatic basis. The pieces can be passed through an oven on a conveyor to attain the proper temperature and after immersion in the plastisol, again passed through the oven to complete the cure.

Industrial parts being coated with vinyl plastisol include electroplating racks, which require masking of exposed metal surfaces from the electrolyte, and electrical socket assemblies. In the latter application, the adherent coating provides a better seal than the boots, gaskets, and grommets previously used. Complete resistance to the penetration of moisture and dust through the socket into the lamp is obtained.

2. Potted Assemblies. The absence of volatiles makes vinyl plastisols useful as potting compounds. With the addition of inert fillers to aid heat conductivity, assemblies of electronic components can be completely immersed until all air bubbles are excluded. On gelation, complete integration of all components is achieved with a significant improvement in overall dielectric properties.

3. Flexible mechanical components. Vinyl plastisols have potentialities as flexible mechanical components where chemical resistance, colorability, ease of fabrication and greater permanence are more desirable attributes than the superior physical properties of molded rubber parts. Vinyl diaphragms, bellows, grommets, and gaskets may give better serviceability than natural or synthetic rubber components when exposed to oils and greases. Evaluation of the application can be made only after consideration of the chemicals to be resisted and the operating temperatures.

Reinforcing lamina, such as woven glass cloth or glass matter, can be inserted in a plastisol during fabrication. This feature has been used in the manufacture of a high quality gasket material. The reinforcing strips become a permanent part of the vinyl plastisol assembly during the gelation process.

The procedure may be carried further in the molding of laminated goods. Parts such as binocular cases, required to be tough and flexible, have been prepared from vinyl films and reinforcing fabrics. These assemblies could be more economically handled by replacing the vinyl film with a wet-lay-up of vinyl plastisol. Parts could be molded to shape under pressure.

Flexible, expandable bags such as those used in the "Greer" type of hydraulic-pneumatic accumulator, would have better oil resistance if fabricated from vinyl plastisol. Also, the growing interest in rubber-lined and rubber-sealed valves for handling corrosive chemicals may well introduce new fields of application for the vinyl plastisols.

4. Electrical Assemblies. The good electrical properties of plasticized polyvinyl chloride compositions have motivated their use in wire and cable construction. The same properties can be obtained with polyvinyl plastisols. While low heat distortion temperature and high creep rates are detriments to many electrical requirements, the required flexibility and toughness may dictate the use of the material.

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STEPS IN DESIGNING ENGINEERED PREPRODUCTION MODELS

1. Initial conferences stating and clarifying the problem.
2. Discussion and study sketches.
3. Test parts if necessary.
4. Making the drawings, preliminary Index, and Bill of Material.
5. Checking.
6. Discussion with the responsible person inside the development organization concerning the state of the design to elicit his suggestions.
7. Detail drawings are given to the shop on preliminary unapproved prints.
8. Designer follows construction closely in the shop, annoting on the shop prints any drawing errors or suggested improvements as they arise, signs or initials the notations, and indicates the date. No shop changes are permitted without the designer's signature on the shop prints during this phase of the work.
9. When the first model has been assembled and modified to the satisfaction of the designer, electrical and other components, and wiring are installed.
10. Performance, shock, shake, humidity, temperature, altitude, and other tests deemed necessary are conducted.
11. A design conference is called and notes are taken by the designer of all suggested design modifications.
12. Drawings are modified accordingly. One objective of this final design phase is the completion of all unfinished work indicated on the reminder sheets.
13. Assembly and subassembly drawings are modified or completed.
14. Index of Drawings is completed.
15. Bill of Material is completed.
16. All drawings, the Index, and Bill of Material are signed to signify final approval.
17. A drawing book is placed in the designer's file.
18. The accumulated material in the notebook is numbered page by page, removed from the notebook, stapled together, and filed in a properly identified folder.
19. The chief engineer and the planning or scheduling departments are notified of the completion of the project.

Engineering Department Procedure in Design of Preproduction Models

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BROADLY SPEAKING, the function of the engineer-draftsman-checker team is the preparation of an Index of Drawings; Bill of Material; assembly, subassembly, and detail drawings; and instruction sheets. In preparing such material this team strives to answer, thoroughly and clearly without the need of further directions from the engineering department, the question: "What do the production and procurement departments need to know, to enable them to present to the sales department one or many economically produced models that fulfill all conditions for which the unit was designed?

In a small company, the designer is often the chief engineer. In a large company producing several types of designs, the designer may be called project engineer, or design or layout draftsman. Whatever the size of the organization, he must organize his work so that the development of his concept of the design proceeds with accuracy, efficiency, and dispatch in order that the work of draftsman, detailer, and checker may be done quickly and correctly.

In a manufacturing organization, new product design may be initiated by the business or sales management, the engineering department, or the research department. In a research and development organization, the nature of the research to be carried on within the organization is generally more or less broadly defined by the management; but the functional purpose of many of such an organization's designs is determined by a client's requirements. These requirements, sometimes in outline form, are initially communicated to the contractor organization in the initial discussion with the client.

The specific details are communicated to the designer in one or more of several ways. (1) The contractor may be given only the broad requirements of the apparatus; he agrees to work out the details. Unless the contracting organization is quite small, the management assigns a

project engineer who will have full design responsibility for the project. (2) The contractor may be given a well-defined set of design specifications to adhere to within certain prescribed limits; the specifications are handed to the designer and he is responsible for the consummation of the project. (3) The nature of the project may be such that continuing discussions between the client and designer will be required as the design progresses.

In all instances, it is necessary for the designer at the outset to obtain as much information as possible concerning the requirements of the projected design. Copious note taking at this stage is recommended. The designer must ask himself: "Do these people know what they really want?" and then proceed tactfully to find out.

He must also ask many other questions: Size? Weight? Quantity? Cost? Time available? Expected life? Operating conditions? Type of operating personnel? Additional factors that he should take into consideration are associated with tax laws, patent laws, accounting procedures, probable final production quantities, selection of materials, and preferences of the client, particularly where cost, quality, and performance are concerned.

Several sugestions may arise and some of them will probably be accepted or rejected on the spot. Probably many skeletal "talking" sketches will be made. These, with the notes, should be carefully preserved. At all times during this and ensuing discussions, the designer must guide himself by a sincere desire to ascertain as exactly as possible the purpose of the design.

When the preliminary discussion is ended, the designer is ready to commence work. At this juncture, having accumulated some notes and sketches, it is well to provide a means of preserving them. A standard three-ring stiff notebook cover serves the purpose very well. Stiff titled cardboard separators for the various divisions of the notebook hould be provided as required.

The notebook is the rallying point for the design. As the designer commences his preliminary thinking, he will probably make numerous free-hand sketches; ask the purchasing agent to request quotations; consult catalogues; and make dated discussion notes as the picture of the design begins to unfold itself. These sketches, notes, requisitions, and records of discussions should be filed in their proper places in the notebook.

Page one in the notebook should be a "Reminder Sheet."

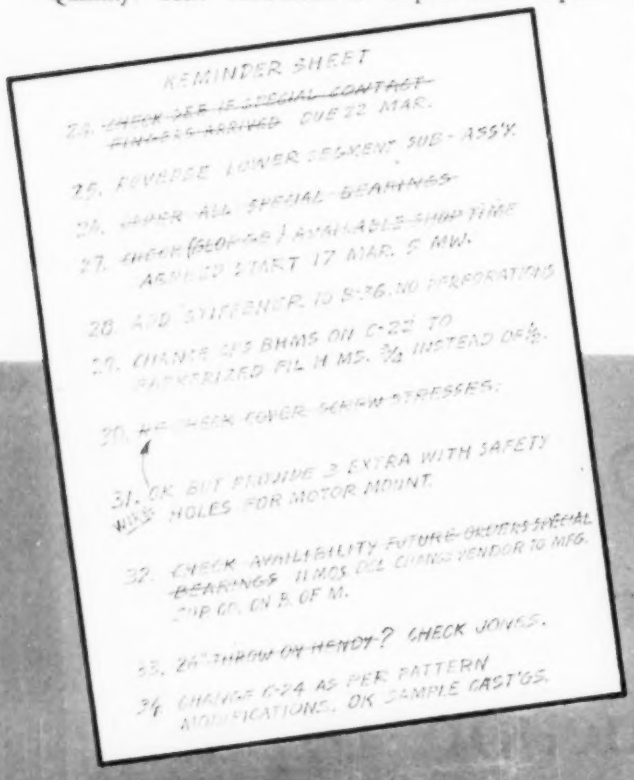
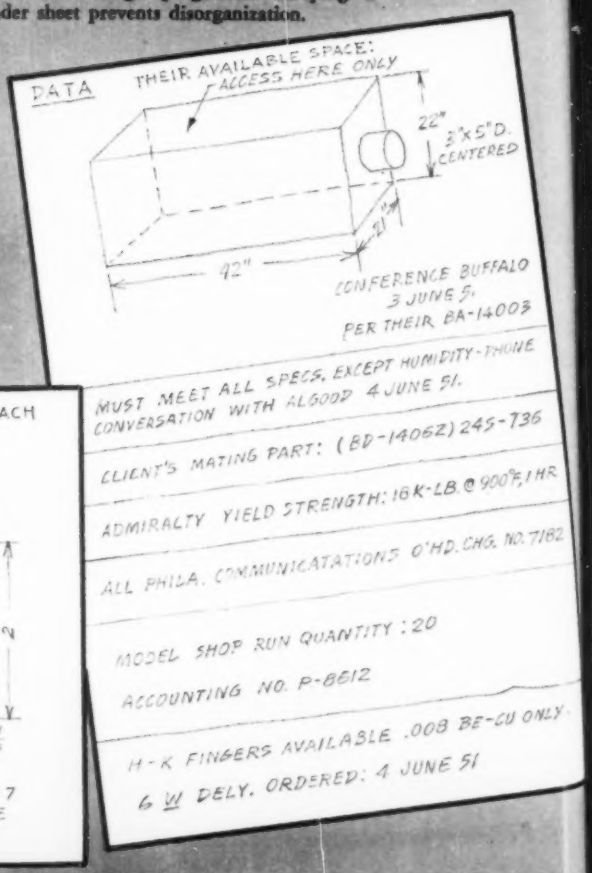
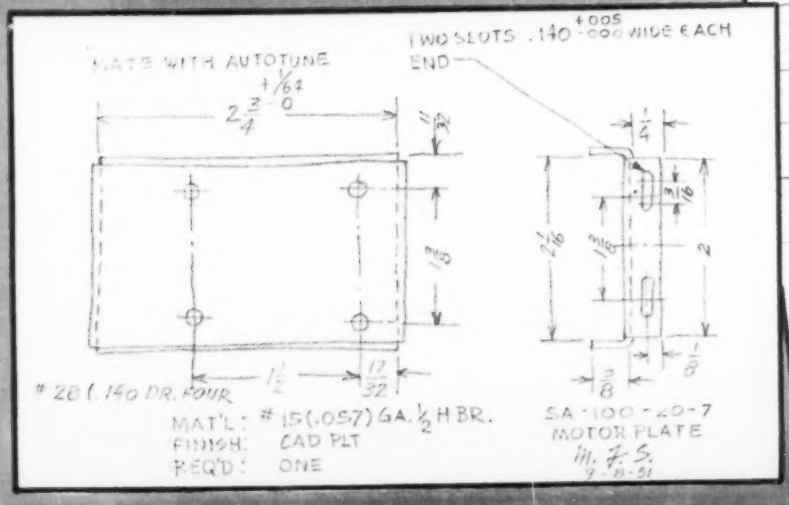

REMINDER SHEET
24. CHECK OUT IF SPECIAL CONTACT FINGERS ARRIVED DUE 22 MAR.
25. REVERSE LOWER SEGMENT SUB-ASS'Y.
26. ORDER ALL SPECIAL BEARINGS
27. CHECK FIELDING AVAILABLE SHOP TIME ARRIVED START 17 MAR. 5 MW.
28. ADD STIFFENER TO S-36, NO PERFORATIONS
29. CHANGE SP3 BHMS ON C-22 TO CADMIZED FILM MS. 3/8 INSTEAD OF 1/2.
30. RECHECK COVER SCREW STRESSES.
31. OK BUT PROVIDE 3 EXTRA WITH SAFETY HOLES FOR MOTOR MOUNT.
32. CHECK AVAILABILITY FUTURE ORDERS SPECIAL BEARINGS 11 MOS. OR CHANGE VENDOR TO MFG. SUP CO. ON B. OF M.
33. 24" THROW OK HENDY? CHECK JONES.
34. CHANGE C-24 AS PER PATTERN MODIFICATIONS. OK SAMPLE CAST'GS.

Fig. 1—Free-hand sketch of a component given to the purchasing agent to accompany requests for quotations.

Fig. 2—Specimen "Reminder Sheet" filed in first section of designer's notebook. On such sheets, loose ends and unfinished business are noted as the design progresses. Keeping a reminder sheet prevents disorganization.


DATA
THEIR AVAILABLE SPACE:
ACCESS HERE ONLY
22"
3"x5"D. CENTERED
42"
CONFERENCE BUFFALO 3 JUNE 51.
PER THEIR BA-14003
MUST MEET ALL SPECS. EXCEPT HUMIDITY-THONE CONVERSATION WITH ALGOOD 4 JUNE 51.
CLIENT'S MATING PART: (BD-1406Z) 245-736
ADMIRALTY YIELD STRENGTH: 16K-LB @ 900°F, 1 HR
ALL PHILA. COMMUNICATATIONS O'HD. CHG. NO. 7182
MODEL SHOP RUN QUANTITY: 20
ACCOUNTING NO. P-8612
H-K FINGERS AVAILABLE .008 BE-CU ONLY.
6 W DELY. ORDERED: 4 JUNE 51



On this page all the loose ends and unfinished business are stored. Most designers will probably agree, that omissions in past designs were not caused by failure to think of things, but by failure to remember to follow through the many little ideas that presented themselves as the design progressed. Keeping a reminder sheet prevents disorganization and promotes peace of mind.

Next, in a "Data" section in the notebook, should come the notes and sketches that are the designer's records of the requirements of the design, discussions and proposals, investigations of materials, and so forth. The designer should preserve his own sketches. These, in addition to possible patent value, are useful records of design features agreed upon in preliminary and ensuing discussions.

Another section should be reserved for "Calculations." Usually, after calculations have commenced, the designer finds it necessary to cut a few corners as delineated by his mathematics, or by space and strength considerations, or lack of experience with the design in point. If so he probably makes a few sketches that he gives to the model shop for the fabrication of trial pieces.

The next major subdivision of the notebook should be entitled "Sketches." In addition to serving as the repository for preliminary layout and study sketches, and sketches of test parts fabricated in the model shop, this subdivision should include small final layout sketches and free-hand sketches awaiting detailing.

All these preliminary shop sketches, prints thereof with shop corrections, suggestions, and test notes should be filed in the notebook. Such data, especially the corrected preliminary shop sketches, facilitate rapid detailing later. They are also of some value in making estimates of shop time and costs if the shop management annotes the time required to make the parts on the respective drawings.

Here it may be well to discuss what often develops as a weakness in the linkage between the designer's imagination and the finished model. This weakness is the lack of concise efficient communication of information to the draftsman or detailer.

There are three ways to get the design on paper:

1. To "talk" the design onto the board of a thoroughly competent layout draftsman by means of pencil and pad and lots of discussion. Usually the layout draftsman works out the details from this point, either drawing them himself or by giving sketches to a detailer.

2. The designer makes a rather detailed and accurate layout, which is presented to the draftsman who proceeds to draw the assembly, subassemblies, and details as required. Such a system requires the services of a draftsman with ability and considerable engineering judgment. Making such a layout involves considerable time and expense, also it is difficult to know just how much information should be presented.

3. The designer makes only such layout sketches as are necessary for him to determine dimensions and configuration of the various parts and the assembled unit. Too-complete layouts waste time. The main purpose of the layout should be to clarify the picture of the design as it exists in the designer's mind, rather than to convey complete dimensional details and other information to the draftsman.

Even with a rather complete design sketch, the draftsman will need to consult with the designer quite frequently; since there is always the question of where to draw the line where layout sketch completeness is concerned. Use of skeleton sketches and the presentation to the draftsman of free-hand sketches of the individual parts specifying dimensions, tolerances, heat-treatment, finishes, assembly instructions, and the numbers for assembly and detail drawings results in accurate and complete drawings. Such sketches also reduce time and effort in designing and detailing to a minimum.

The reader may wonder how drawing numbers can be specified at this time. So it may be well to digress briefly to discuss the last section of the notebook. This section is composed of the rough drafts of the Index of Drawings and Bill of Material. In making the drafts for the Index of Drawings, titles are chosen for the assembly, subassembly, and individual part drawings as they appear on the design sketches. At this time, numbers are assigned in sequence as the titles are set down in the Index in numerical order under the respective subassembly headings.

With a little care, foresight, and experience, the groupings can be chosen logically so that subassemblies that are adjacent to each other in the main assembly are adjacent to each other in the Index of Drawings. Individual parts that are adjacent to each other in the subassemblies are adjacent to each other in the Index of Drawings. Thus, numbers and titles for practically all drawings are available before detailing commences.

As numbers are assigned, it is well to give to the purchasing agent a preliminary list of the parts to be purchased. Such foresight diminishes the chances of delay when assembly of the first model commences.

Returning to the detailing of the individual parts, the designer can now supply sketches, complete with titles and numbers, to the detailer who needs do little more than copy off the information onto a sheet of drawing paper.

After the detailer has completed the drawings, he should

Fig. 3—Data Sheets are the designer's record of design requirements, discussions, proposals, and investigations of materials.

Fig. 4—Designer's "talking" sketch supplemented with discussion enables draftsman to work out details.

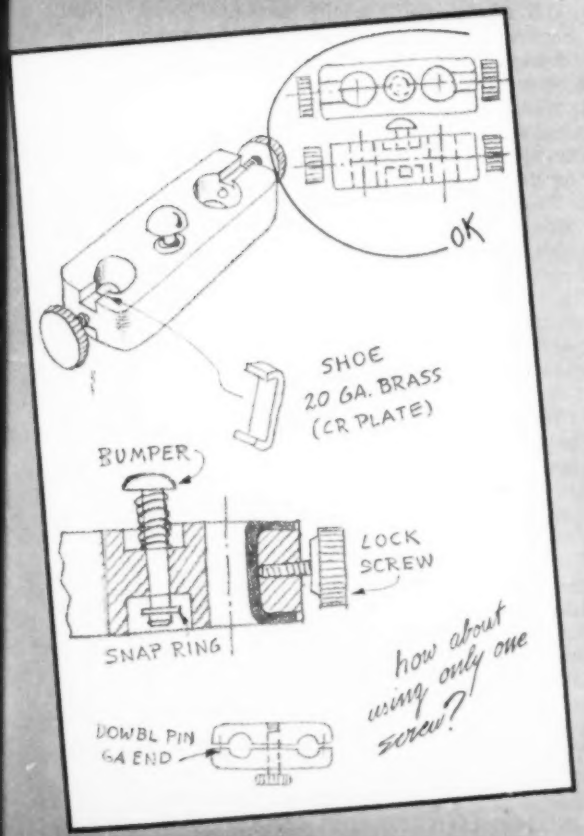
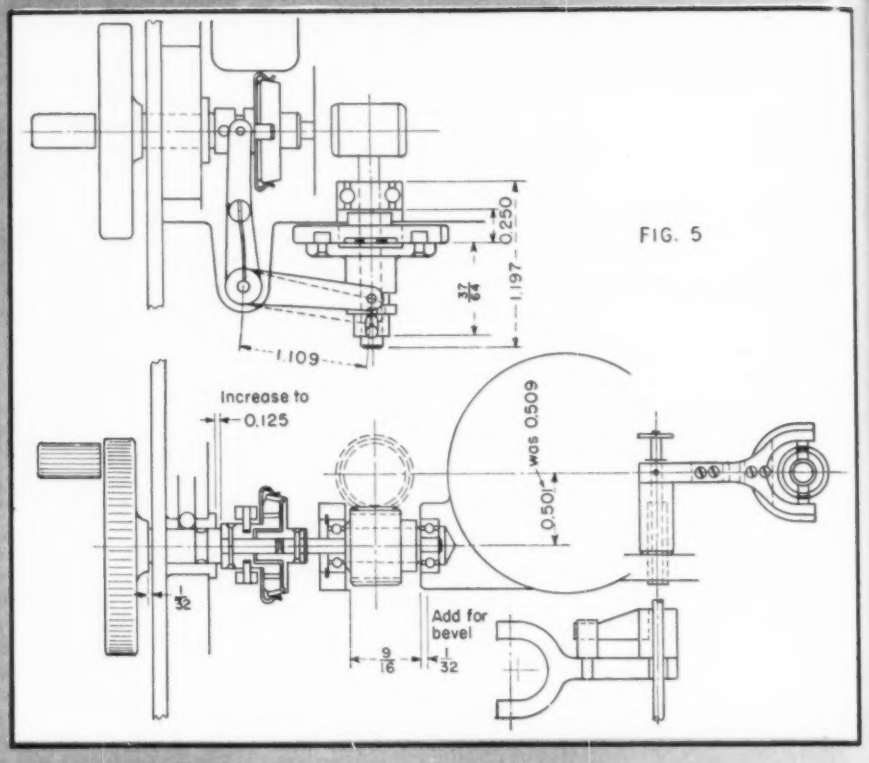


Fig. 5—A detailed and accurate layout made by the designer from which the draftsman draws the assembly, subassemblies and details. Such a layout involves considerable time and expense, also it is difficult to know just how much information should be presented. This method requires that the draftsman must have considerable engineering judgment.

Fig. 6—Drawing list made up from rough drafts of the Index of Drawings. Numbers are assigned in sequence as the titles are set down in the Index in numerical order under the respective subassembly headings. With this method, numbers and titles for all drawings are available before detailing commences.



deliver checking prints, drawings, and sketches to the checker. These drawings will be unapproved at this stage. Since most companies have a definite procedure for identifying prints of unapproved drawings, either by the color of the print or by a suitable stamp or notation, any prints made at this stage must conform to such practice. The checker can mark on the prints or original sketches his corrections, modifications, and deletions in red pencil when checking against the designer's sketches and the standard's manual.

If the job is relatively small and simple, checking prints may be dispensed with and only the original drawings and sketches delivered to the checker, who annotes the few changes and corrections on the sketches, which he clips to the original drawings as checking is completed.

Checking is mainly a matter of asking one's self questions and looking to the drawings for the presence and correctness of an answer. A preliminary check should be given the details as they come off the board. Secondly, all drawings should be given a comprehensive check in accordance with the following principles.

1. Orderliness is important. The assembly should first be checked for general design simplicity, substitution of cheaper or standard parts, and ease of assembly. Next, all assembly and subassembly drawings should be given a quick inspection for general layout, drafting excellence, and whether or not there are immediately detectable omissions.

2. Choose the governing features and dimensions of the design and work outward. Keep the reminder sheet at hand for annoting ideas not directly concerned with drawing checking, such as omissions from the parts lists, tooth forms, electrical insulation, and materials.

As the checker gets deeper into the pile of prints, questions will arise that will require checking "ahead." Also, questions will arise that will call for a reexamination of the "checked" stack. But the process should be kept orderly without sacrificing thoroughness.

3. Materials should be checked for electrical characteristics, wear characteristics, corrosion resistance, fungus resistance, thermal distortion, and other properties depending on the application of the design.

4. Finally, the assembly should be checked for the clarity of views, and the simplicity of identification of each subassembly, individual fabricated part, purchased part, nut, bolt and screw.

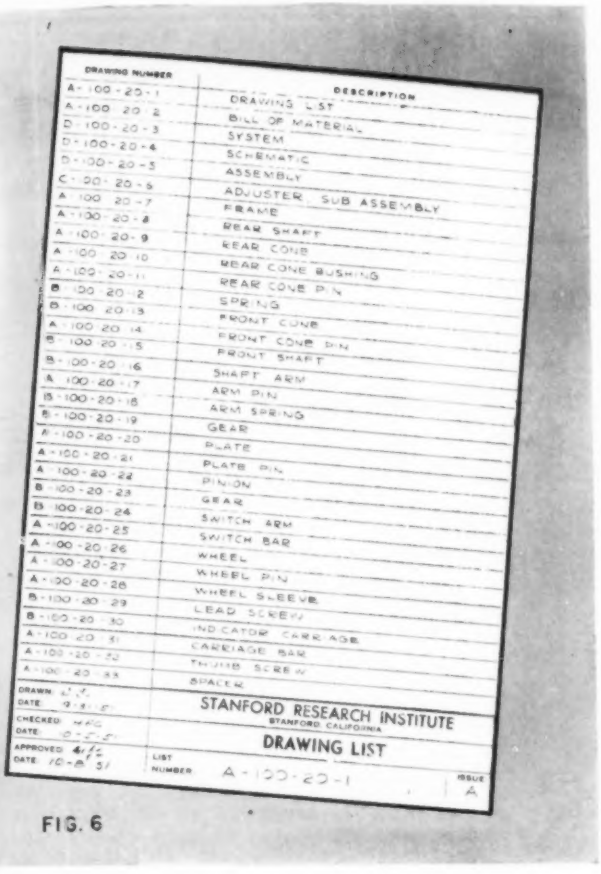
The assembly instructions should be checked for clearness, and coverage of such subjects as lubrication and special masking or finishing. The assembly check will probably uncover some necessary detail modifications.

If the design is a contractural development, the drawings, Index of Drawings, and Bill of Material should be thoroughly checked for compliance with the client's specifications.

All drawings, the Index of Drawings, Bill of Material, and instruction sheets should be checked for completeness and correctness of title-box information.

Checking should be completed by checking the integrity of the main assembly drawing. The assembly should be scrutinized from as fresh a view point as possible, inasmuch as the assembly drawing is the gateway to the determination of answers to many questions that arise after the drawings have been initially delivered to the drafting room files. These answers may possibly entail some changes on parts that have already been checked.

After checking, the drawings should be returned to the



DRAWING NUMBER	DESCRIPTION
A-100-20-1	DRAWING LIST
A-100-20-2	BILL OF MATERIAL
D-100-20-3	SYSTEM
D-100-20-4	SCHEMATIC
D-100-20-5	ASSEMBLY
C-100-20-6	ADJUSTER SUB ASSEMBLY
A-100-20-7	FRAME
A-100-20-8	REAR SHAFT
A-100-20-9	REAR CONE
A-100-20-10	REAR CONE BUSHING
A-100-20-11	REAR CONE PIN
B-100-20-12	SPRING
B-100-20-13	FRONT CONE
A-100-20-14	FRONT CONE PIN
B-100-20-15	FRONT SHAFT
B-100-20-16	SHAFT ARM
A-100-20-17	ARM PIN
B-100-20-18	ARM SPRING
B-100-20-19	GEAR
A-100-20-20	PLATE
A-100-20-21	PLATE PIN
A-100-20-22	PINION
B-100-20-23	GEAR
B-100-20-24	SWITCH ARM
A-100-20-25	SWITCH BAR
A-100-20-26	WHEEL
A-100-20-27	WHEEL PIN
A-100-20-28	WHEEL SLEEVE
B-100-20-29	LEAD SCREW
B-100-20-30	INDICATOR CARRIAGE
A-100-20-31	CARRIAGE BAR
A-100-20-32	THUMB SCREW
A-100-20-33	SPACER

DRAWN: J.S. DATE: 9-8-51
CHECKED: H.A.C. DATE: 10-2-51
APPROVED: A.F.S. DATE: 10-8-51

STANFORD RESEARCH INSTITUTE
STANFORD, CALIFORNIA

DRAWING LIST

LIST NUMBER A-100-20-1 ISSUE A

FIG. 6

designer in whose responsibility the final design rests. He makes such additional modifications or corrections of the checking prints as he deems necessary. Prints and drawings are then returned to the drafting room for correction. The original sketches should be placed in the notebook. After correction, the drawings and checking prints (or sketches) should be given to the checker for final checking.

The checker should recheck the corrections and sign the "checked by" box on the individual drawings and lists. All drawings should then be returned to the designer for a final inspection and his written signature, signifying his assumption of design responsibility.

After final checking, unapproved prints are made for the model shop and the drawings are filed in the designer's file (separate from the print room file). The reason for such filing is that up to the time of approval of completed drawings, completion of the first model, or completion of the Index of Drawings and Bill of Material, any drawing changes can be made under the authority of the designer without the necessity for formal notation of the changes either on the drawings or in the drafting room.

Usually only subassembly and detail prints are given to the model shop, especially if time is limited. The shop foreman should rely upon the designer to answer any question that may arise concerning the model. The designer should follow closely the assembly of the model in the shop, noting on the reminder sheet or the shop drawings any changes that suggest themselves. If he follows this procedure, minor corrections and changes of the drawings will be available by the time the first model emerges from the shop.

The model should be photographed as completely as possible. These photographs often prove useful later when the engineering and drafting departments are concurrently inspecting, measuring, testing the model and modifying the drawings.

In addition to testing its ability to fulfill the primary function for which it was designed, the model should be thoroughly tested in the range of such parameters as temperature, humidity, vibration, and resistance to shock.

After the model has been thoroughly tested, a more or less formal conference should be called. This conference should include the chief engineer, production engineers, development engineers, purchasing agents, possibly the client (if it be a contractural development), chief draftsman, and others who may be in a position to contribute to the excellence of the final model.

The primary purpose of the design conference is twofold: It gives an opportunity for all persons responsibly connected with the design to express approval of the design, and to make suggestions for modifications.

Although the production department is represented at the final design conference, undoubtedly production problems will be encountered in the shop and on the assembly line. Also, such factors as customer appeal and servicing in the field may result in requests by the sales department or client for other modifications subsequent to the deposition of the drawings, Index, and Bill of Material in the permanent file.

After the design conference, all drawings, the Index of Drawings, and Bill of Material should receive final modification. One objective of this final design phase is the completion of all unfinished work indicated on the reminder sheets.

The assembly and subassembly drawings, Index of Drawings, and Bill of Material can now be modified and completed, making use of the shop drawings with pencilled-on corrections and changes, and the design conference notes.

Usually final approval of the design rests with someone in the company other than the designer.

Some companies require that all drawings, Indexes, and Bills of Material be signed. In other organizations, final design approval of the major assembly and sub-assemblies is the responsibility of the chief engineer or other officer, the designer being responsible for correctness and completeness of all detail drawings, the Index, and Bill of Material.

The signed drawings, Index, and Bill of Material should be placed in the permanent file to be drawn upon for printing as needed by the production and purchasing departments, and others; and the chief engineer should be formally notified of completion of the job.

After approval signatures have been obtained, a complete book of the approved drawings, Index of Drawings, and Bill of Material should be placed in the designers file for handy reference.

Sooner or later, additional changes of the design will be suggested, or questions arising in the shop or other departments will come to the attention of the designer requiring consultation of the drawing book.

Any changes deemed necessary can be pencilled on the proper print in the drawing book. This print should be removed from the book, attached to a "Request for Drafting Change" form and forwarded to the drafting room. After the change has been made, the corrected drawing and pencilled-up print should be turned over to the checker, who checks the drawing against the print and then returns approval signatures. The drawing is then returned to the file and the marked-up print is placed in a "Changes" folder in the designer's file. A new print of the changed drawing is then placed in the designer's book, bringing it up to date. A similar procedure applies to changes in the Index of Drawings and Bill of Material.

Basic Design for Small Part

Recommended practice for the design of simple stampings, including design for

RELIEF NOTCHES FOR RIGHT ANGLE BENDS

Fig. 1—If the outside of the bend is parallel with the profile of the blank, regardless of the radius, a certain amount of fracturing or tearing of the material will be introduced, *A*. This tearing will be increased or decreased, depending upon the amount of radius on the outside of the finished formed part. A common method used to correct fracturing or tearing, is to introduce notches for relief, such as shown at *B*. These relief notches can be produced in the profile of the flat blank, and should at all times be twice the thickness of stock in width, and twice the thickness of stock in depth, when design permits. This latter blank design gives a more satisfactory bend and more rigidity in the bent section.

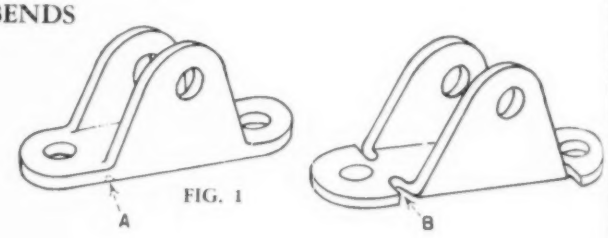


FIG. 1

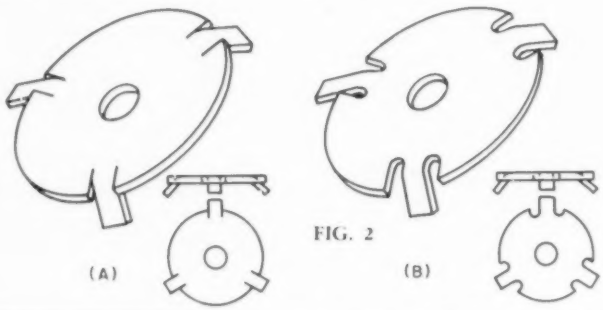


FIG. 2

Fig. 2—While compound dies or multiple purpose one-operation dies are advisable for mass production, tools that will produce in one operation what is ordinarily being produced by two or more are advisable from quantity production standpoint. The design at (*A*) should be avoided when small lot stampings or pilot runs are being considered. The lancing tool not only has to lance the three ears loose, but also has to form and set the ears. The forming tools used for (*B*) merely form and set the three ears in their desired position on the finished blank.

PIERCED HOLES RELATIVE TO RIGHT ANGLE BENDS

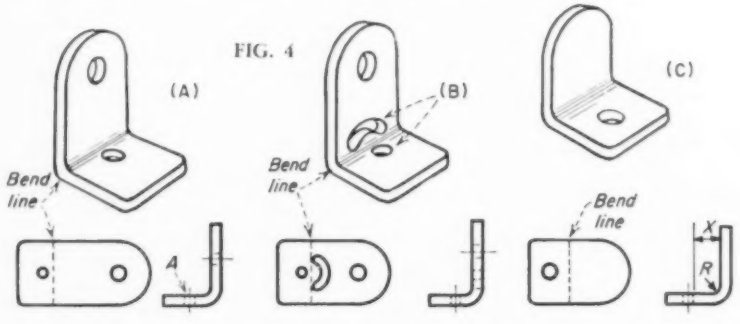


FIG. 4

Fig. 4—Right angle bends, relative to a given hole location, are rather difficult to maintain to any high degree of accuracy, as there are two basic conditions which may change the position or relative location of such hole. These conditions are stock thickness variation and temper variation of stock. Often a hole must be made as close as possible to a right angle bend, *A*. In this case a normal pierced hole must be made after the bend, otherwise a distorted hole, will occur. The same blanked and pierced part is shown at *B* redesigned with the addition of the crescent slot. This design allows the part to be die-cut, blanked and pierced. There is enough flat material left around the desired pierced hole so that no distortion of material thickness affects the finished hole in the bending operation. Stock left adjacent to the hole should not exceed the material thickness of the stamping specification. Although this design is not always possible, it should be considered from the standpoint of mass production. The desirable location of placing the hole adjacent to a right angle bend, is at *C*. The edge of the hole should not be closer than one and one-half times the thickness of stock, plus the inside radius of the right bend.

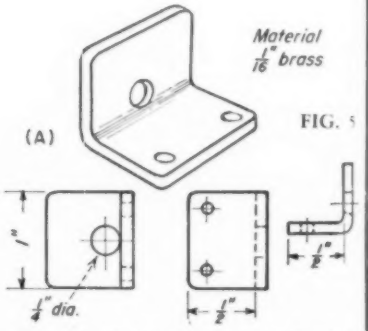


FIG. 5

Fig. 5—Shows a piece part with the edge of a large hole in line with the bent section of the finished part. This bend would distort the hole considerably, particularly if the stock

Stampings

D. A. RODGERS
President, Dayton Rodgers Manufacturing Company

forming and bending, relief notches for right angle bends, tolerances on mating

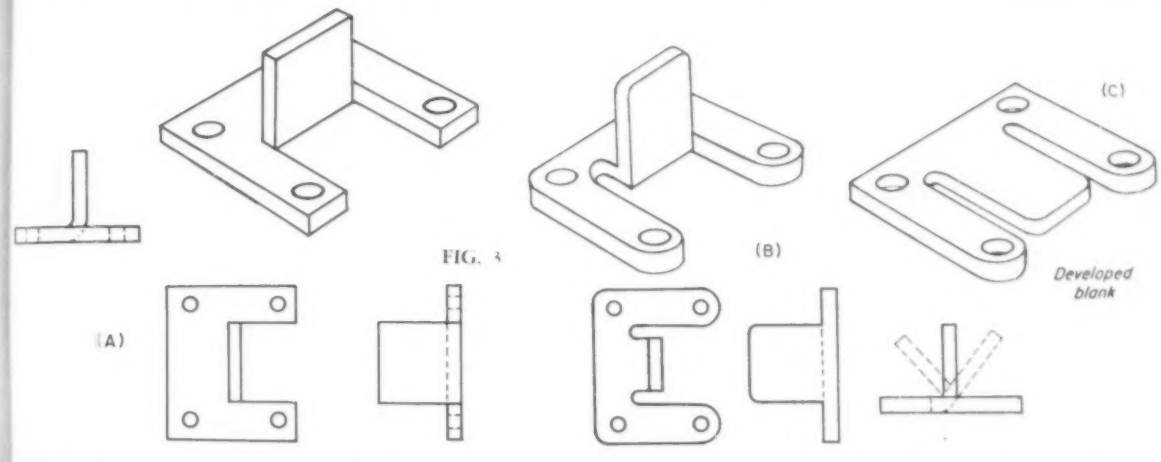


FIG. 3

The six nicks or recesses adjacent to the ears should be in width at least twice the thickness of the stock, and should be somewhat deeper than where the bend takes place on the finished formed part. The radius at which the ears meet the major blank can be increased or decreased without affecting any additional tool cost, and the ears may be laid at almost any angle assuring a free position of the finished part.

Fig. 3—Typical lanced piece, *A*. The correct free position of the ear would be hard to maintain on a high degree of accuracy; also, the radius at the bottom could not be held too constant. The best designs for pilot runs of such blanked, pierced and formed parts are shown at *B* and *C*. It should be noted that this ear can be formed at any angle with any desired radius at the bottom without difficulty.

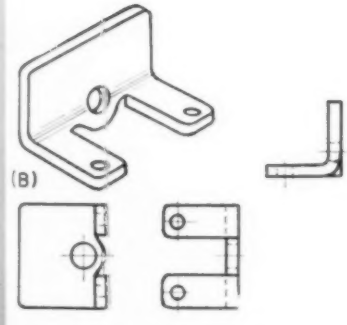
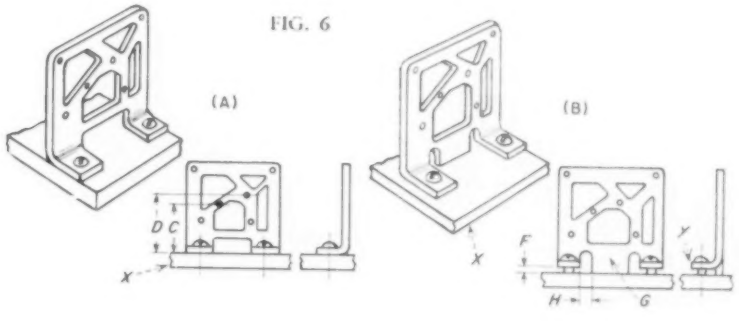


FIG. 6



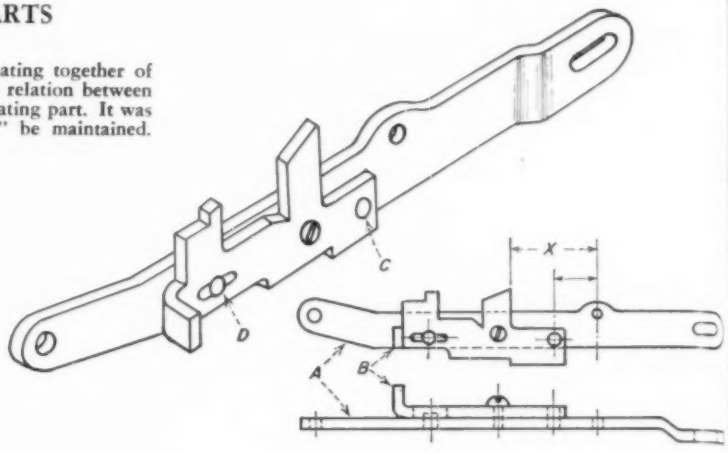
thickness was more than 0.015 in., and would make an undesirable hole in the finished formed stamping. The piece part is redesigned at *B*, keeping the edge of the large hole in the required position to the right angle bend. This was accomplished by the redesigning of the blank and the pierced flat stamping. If this redesign is not always possible, and if the design shown in *A* has to be maintained at no time should the edge of the pierced hole in a given part be closer to the bend than one and one-half times the stock thickness plus the inside radius of the bent section, if the hole is to be pierced before forming. In design A, a normal pierced hole must be made after the bend, otherwise a distorted hole will result.

Fig. 6—The original design, A, shows the part as submitted, while B shows the converted design used for a gear train plate. In this particular case it was necessary to fasten two plates to a common base X. In bending or forming the ears Y, a slight variation in stock thickness or material temper will increase or decrease the dimensions C and D, causing the bearing holes to be out of line in the final assembly. Using design B, the ears Y, were formed in such a manner that there was a slight clearance left at F on both ears. When it was required to line up two such plates, this was accomplished by letting the added section G of the stamping come to rest on the base X. In the design of section G the stamping was notched at H. *(continued on next page)*

TOLERANCES ON MATING PARTS

Fig. 7—If extruded dowels are used in the mating together of two parts, it is usually done to hold a definite relation between a point on one part and a given point on the mating part. It was essential in this case that the dimension "X" be maintained.

While the two dowels were extruded in part A, the location of the dowel C and the hole in part B were the determining factors of holding the relation "X". The second dowel D was placed as far away as possible from the dowel C, and merely held the alignment of part B. The compensating hole for dowel D was an elongated hole. All that was necessary was to maintain the correct diameter of both dowels, the correct diameter of the hole C, and the correct width of the elongated hole. This made it possible to replace part B whenever necessary.



PIECE PART REDESIGN

Fig. 9—In producing a limited number of blanked, pierced and formed parts at a minimum tool cost, redesign of the part is often considered first.

Part A is a hinged key with a conventional type curled hinge construction, and unimportant overall detail. The hinge section required two or more operations. Part B gave more economical tooling, and was about half that of part A. The only change was to move the hinge pin hole as far as possible from the bent section at A, producing the part in two operations.

FIG. 9

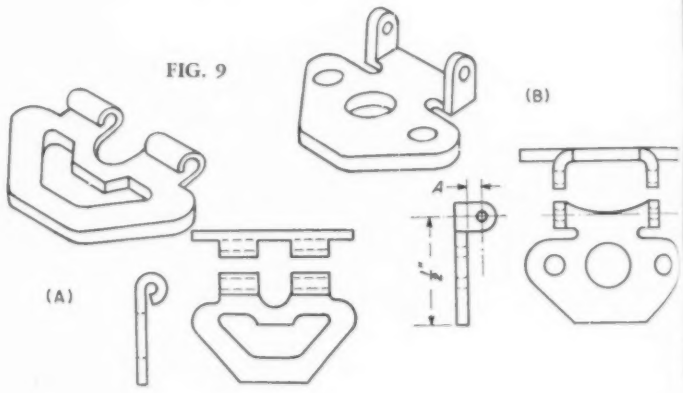


Fig. 10—A simple clevis will demonstrate to the designer or engineer a variety of possible designs for a new piece of equipment. It also

EXTRUDED HOLES FOR TAPPING

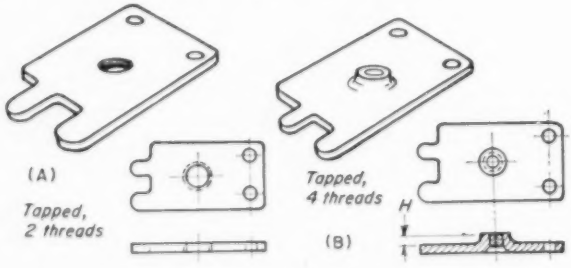


Fig. 11—In the piercing and tapping of sheet metal stock, the possibility of an extrusion at the point of tapping should be considered. The maximum height H of the extrusion should not exceed 1/5 of the body size of the tap. In A, with an 8-32 thread, only two threads could be produced. In B, 3½ to 4 threads would be possible. If possible, instead of using an 8-32, a 10-32 could be used, thus increasing the hole size, and height H.

FORMING AND BENDING SHEET STOCK

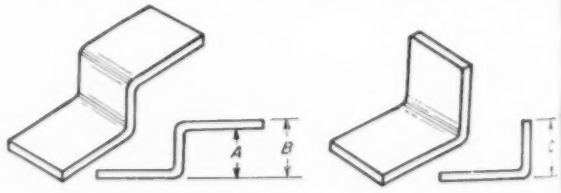
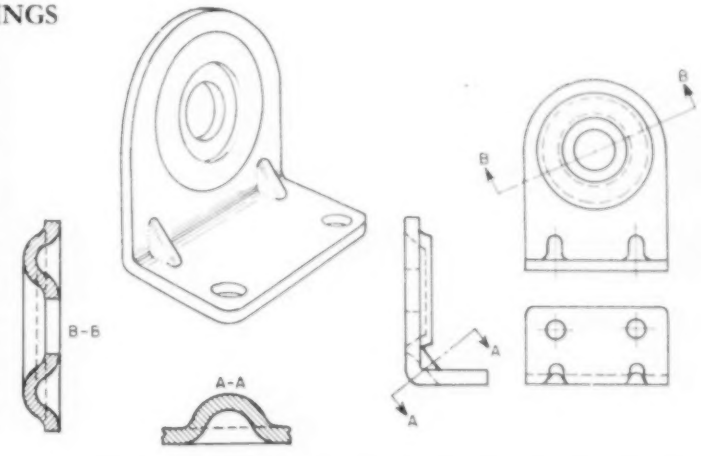


Fig. 12—The overall tolerance of stock thickness should be considered if any high degree of accuracy is wanted in the bending or forming of sheet metal. The two types of steel used in bending operations are: strip steel, and sheet steel. Should the sheet metal vary 0.001 in thickness, dimension A would have an overall variation in the stock thickness plus a small accumulated error in the bending operation itsel.. On the other hand, if dimension B is taken from the outside of the offset bend, the variation would be twice that of A, plus the tolerances required in the forming or bending operation. Cold rolled strip steel has about a 50 percent closer thickness tolerance than cold rolled sheet steel.

REINFORCING RIBS ON STAMPINGS

Fig. 8—Usually in a right angle bent sheet metal part, the bend offers a weak point. In this case, one or more stiffening ribs, such as section AA put at the right angle bend, increase the rigidity of the overall part about 100 or 200 percent. Such ribs can be twice the thickness of the stock material in their overall height, and the inside radius of the rib, if possible, should be equal to the stock thickness.

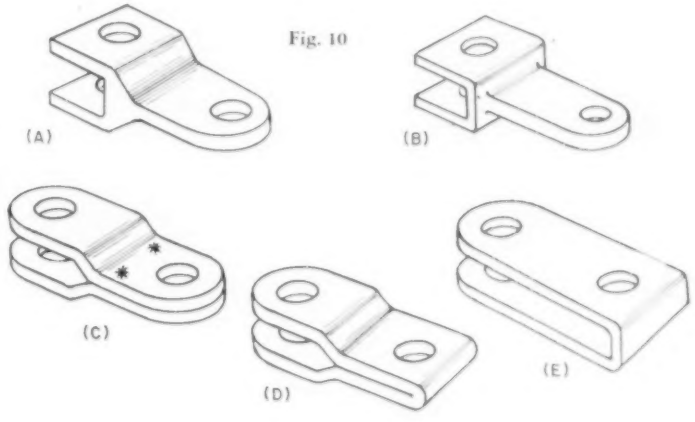
If the hole shown is not a lightening hole, and has a definite purpose, a rib, section BB, may be formed around the hole midway between the hole circumference and the edge of the part. By keeping the ribbing as far as possible from the pierced hole, less distortion of the finished part is assured. The reason being that the contour of the blank is made first, the holes second, and the ribbing last.



gives a practical and economical viewpoint to simple, small parts.

Part A is a casting which does a satisfactory job but adds considerably to the weight of the unit, and is high in price. Part B is a piece of milled-out bar stock welded to a stamping. The design is better; however, the welding, and drilling of holes after welding, adds to the price. Part C shows two symmetrical stampings spot welded together, resulting in good design. A simple inexpensive jig will assure alignment of the holes during spot welding. Part D shows a one-piece stamping involving simple operations, and assures uniformity as to the alignment of holes. Part E is prabably the ultimate as far as simplicity of design and practicability are concerned. All holes are pierced in the flat blank, and a simple U-form will assure very close alignment of holes.

Fig. 10



APPLICATIONS

FIG. 14

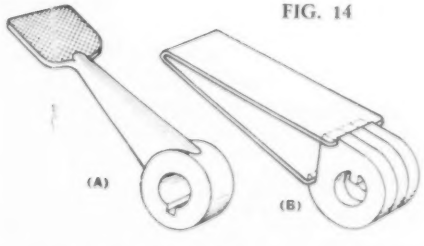
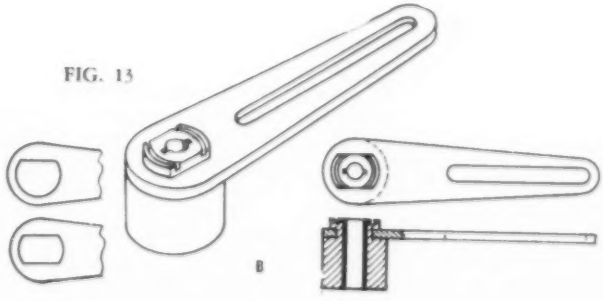


Fig. 13—In transmitting a rotary action to a reciprocating action on a given lever, one flat on the shouldered bushing B is sufficient. Two flats on a shouldered bushing can be milled in one operation, permitting twice the holding power when the parts are put together. The pierced hole in a blank with two flatted holes costs no more, and in a long run is more satisfactory.

Fig. 14—Part A shows a traditional casting and bar stock construction of a machine foot lever 10 in. long with broached keyway, and weighing 6 lb. Part B shows a stamped construction with a saving of about 67 percent. It is just as strong and weighs less. The broaching of the keyway is eliminated as the hub, which is made up of three identical stampings, has the integral key stamped in them. The arm, which is made of 10 gage steel, can be brake formed and welded into position as shown. The overall weight is is approximately 2.2 pounds.

FIG. 13



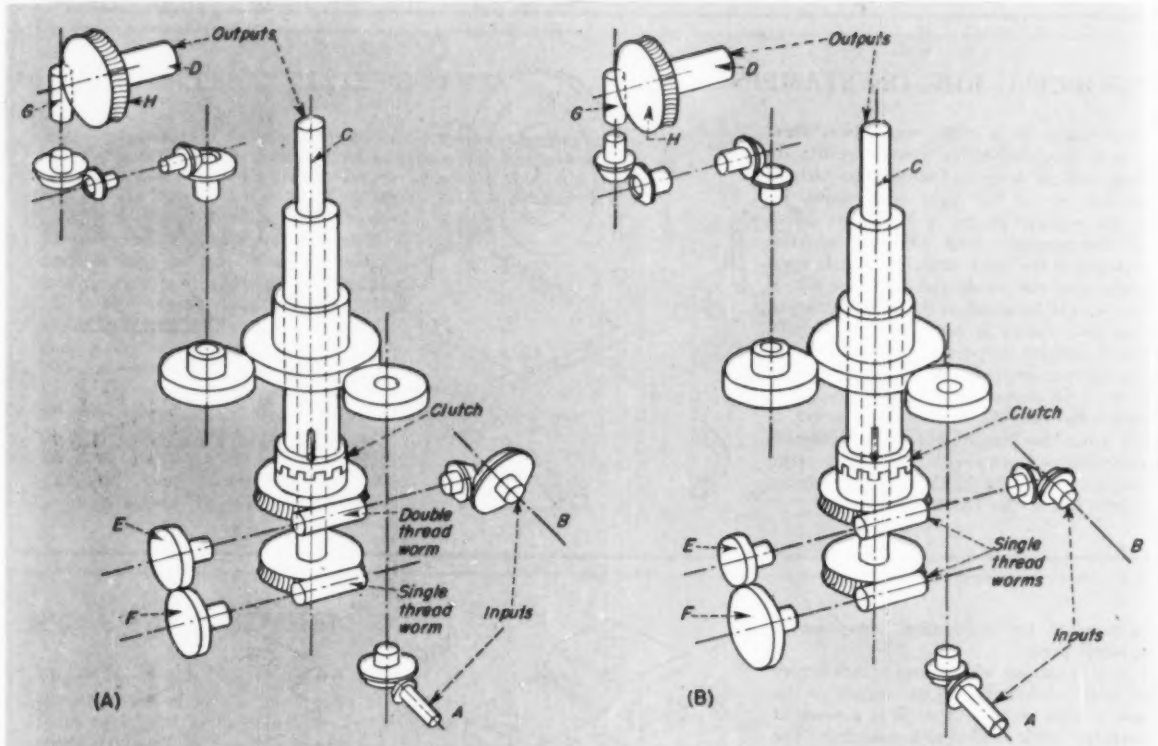


Fig. 1—(A) Original design of gear train for optical instrument.—(B) Revised design in which manufacturing advantages and improved performance are obtained.

Optimum Selection of Gears for

L. M. DAVISON

MANY FUNCTIONAL and cost advantages are lost in instrument gearing when an improper choice is made of the gear type. To meet cost and accuracy requirements of instruments, an expert knowledge of gearing and a full appreciation of the importance of gearing function are required.

Instrument gear trains are composed of many different types of gears that include spur, helical, bevel, worm, and occasionally special non-circular gears. The latter are used on optical instruments to transmit motions that agree with some mathematical function. Most of such gearing is not as highly stressed as that for power transmission. The chief function of instrument gearing is to transmit motion at a desired rate, and to retain that rate for the life of the instrument.

Some designers of instruments are prone to overlook the practical considerations affecting the overall function of the gearing. It is also apparent, in reviewing many gear train designs, that cost considerations have not been too closely scrutinized. It frequently happens that a critical study of a gear train by those qualified to do so, generally results in improved accuracy and reduced costs. Simplification invariably accomplishes these two objectives.

A review of a typical gear train for an optical instrument before and after submission to expert study will demonstrate one way in which design can be improved. Exactly what the instrument does is immaterial to this discussion. As shown in Fig. 1, the system has two input sources *A* and *B*, and two output sources *C* and *D*. Optical elements are rotated by shafts *C* and *D* at a desired rate, through several different types of gears. In the first design, Fig. 1 (A), the drive to the output shaft *C* begins with a pair of bevel gears of unequal ratio (non miters) and proceeds through a double threaded worm and several spur gears. The drive to the other output shaft *D* starts at another pair of non miter bevels, continues through several spur gears, proceeds through a second pair of bevels, and then through a worm and worm gear.

In this train there are four sets of bevel gears. All four sets are slightly different from each other in ratio and blank dimensions, therefore, eight blanks of different dimensions are needed.

Several things are wrong with the design of this gear train. First, it goes through increasing and decreasing speed rates to achieve the final output reduction; second, accuracy in angular transmission is reduced by using a double-threaded worm and gear and un-

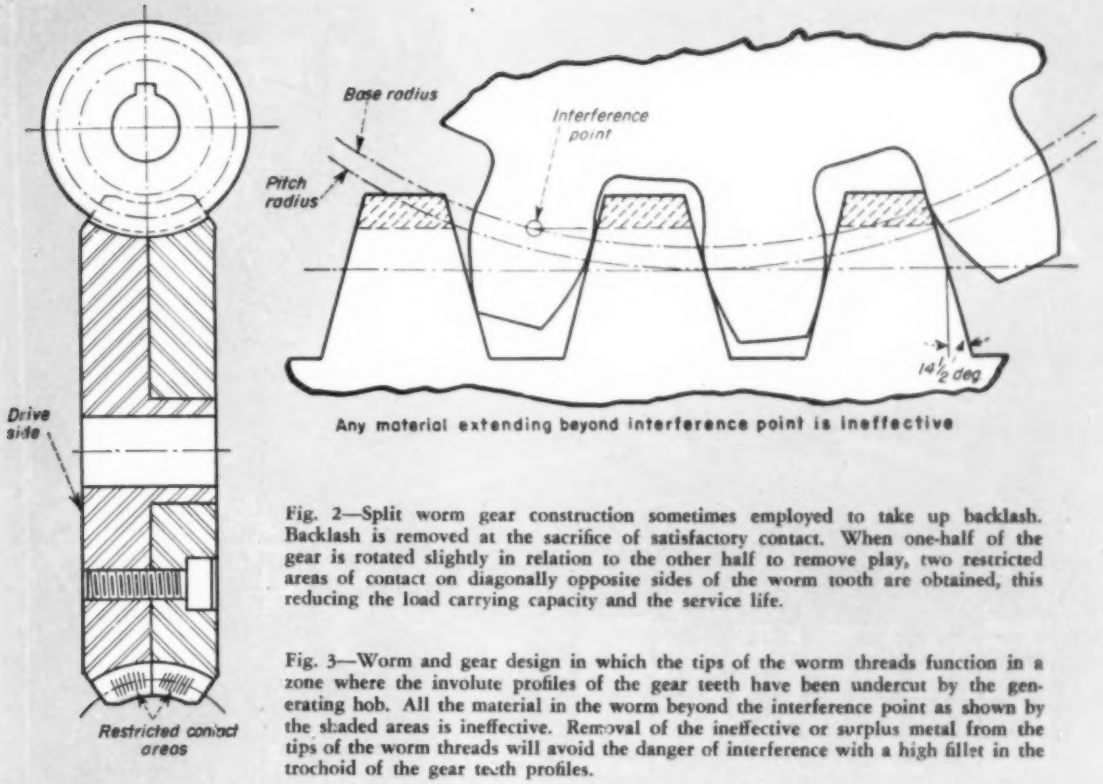


Fig. 2—Split worm gear construction sometimes employed to take up backlash. Backlash is removed at the sacrifice of satisfactory contact. When one-half of the gear is rotated slightly in relation to the other half to remove play, two restricted areas of contact on diagonally opposite sides of the worm tooth are obtained, this reducing the load carrying capacity and the service life.

Fig. 3—Worm and gear design in which the tips of the worm threads function in a zone where the involute profiles of the gear teeth have been undercut by the generating hob. All the material in the worm beyond the interference point as shown by the shaded areas is ineffective. Removal of the ineffective or surplus metal from the tips of the worm threads will avoid the danger of interference with a high fillet in the trochoid of the gear teeth profiles.

Precision Instrument Drives

Design simplifications that improve the performance and reduce the cost of gear trains for instruments. Functional and manufacturing advantages inherent in the several types of gears used in the construction of instruments.

even ratios in bevel gears; and third, manufacture of the gearing is needlessly complicated thereby increasing the cost.

An improved design of the gear train shown in Fig. 1 (A) is shown in Fig. 1 (B). All the bevel gears are miters (one to one ratio), thus it is possible to match the high point of the run-out of one gear with the low point of the run-out of its mate. This practice is common in precision bevel gearing, and leads to greater accuracy. In most bevel gear assemblies, when the ratio is one to one, practically all of the effect of run-out can be cancelled out in this manner.

By making minor changes, it was possible to design a common blank for all the bevel gears and thus achieve two manufacturing advantages: (1) One tool setup to bore, turn, and face eight blanks; and (2) All gears can be cut and inspected with one set of tools.

The double-threaded worm was changed to a single-threaded worm and the worm gear changed to suit so that their ratio and dimensions would be identical with the lower worm and gear. This change was made possible by changing the ratio of spur gears *E* and *F*, from 1:1 and 2:1. Again, this change resulted in greater accuracy and manufacturing advantages. Accuracy-wise, the single-thread worm combination is preferred. Cost-wise, since two worms and gears are alike, the same part and tooling can be used for both combinations.

The desired speed of the output shaft *D* was obtained by increasing the ratio between the worm *G* and gear *H*. In this particular mechanism, it was possible to effect a change in ratio and still maintain the same center distance, merely by using teeth of finer pitch.

In instrument gear designs, one finds many errors committed in the cause of expediency. If a few fundamental principles were understood, these errors could be avoided. In the article "Practical Considerations in In-

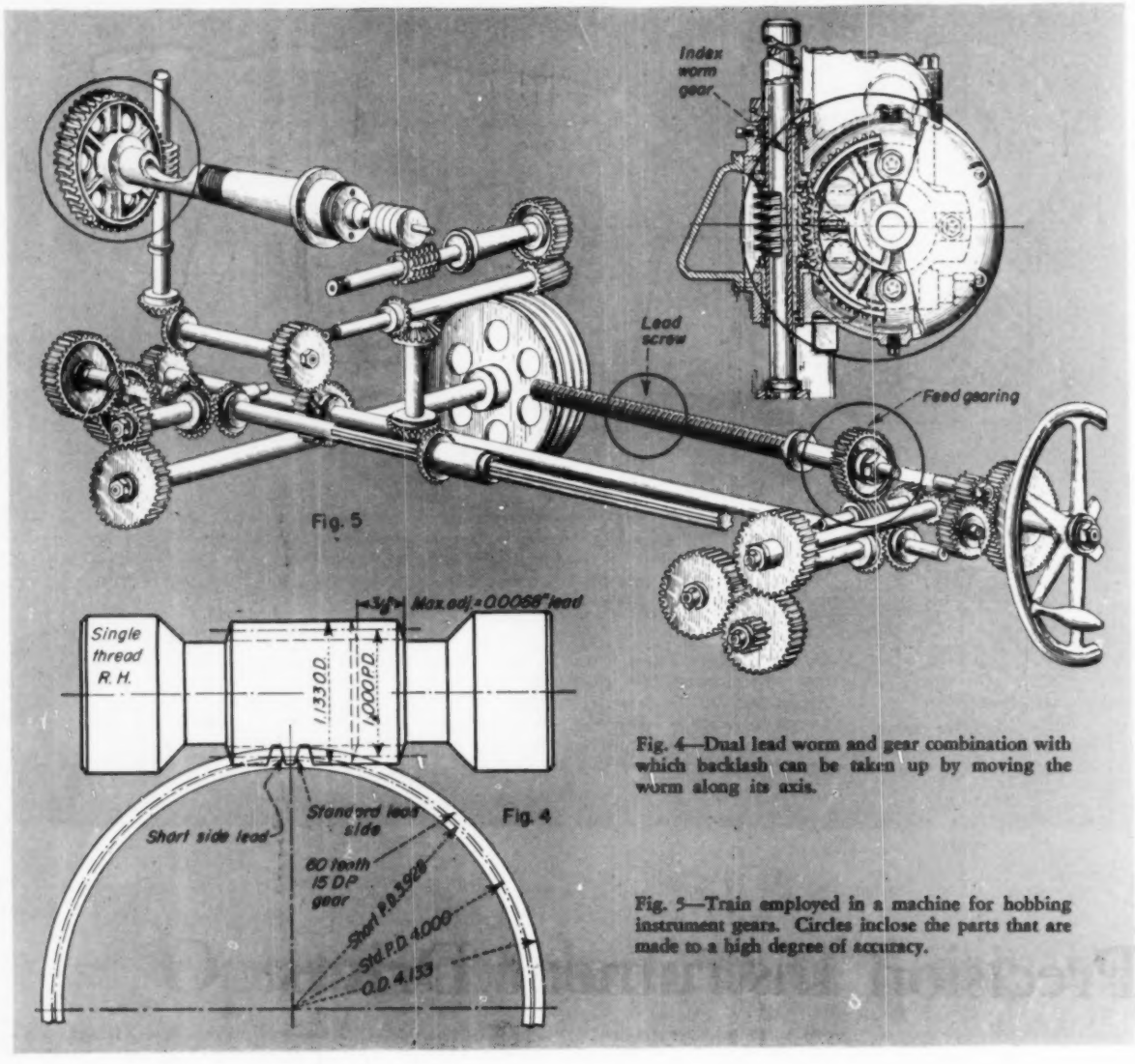


Fig. 4—Dual lead worm and gear combination with which backlash can be taken up by moving the worm along its axis.

Fig. 5—Train employed in a machine for hobbing instrument gears. Circles inclose the parts that are made to a high degree of accuracy.

strument Gear Design" PRODUCT ENGINEERING, September 1951, p 183, attention was directed to the fallacy of using low pressure angles such as 14½ deg in preference to the commonly accepted 20 deg pressure angle, which has become an American standard for fine pitch gears. While the discussions in that article centered around spur gearing, they are equally applicable to worm gearing.

The American Standard for worm gearing, known as ASA B6.9-1950, covers worm gearing of fine pitch, in which category practically all instrument gearing falls. The pressure angle used in this standard is 20 deg. This standard is a step toward simplification of a branch of gearing not generally understood too well, and one which has been a holy of holies for many years. Instrument gear designers would do well to follow this standard.

An example of poor worm gear design is shown in Fig. 2. This split gear construction is sometimes employed to take up backlash. In such a construction, backlash is removed at the sacrifice of satisfactory contact. When one half of the gear is rotated slightly in relation to the other half to remove play, two restricted areas of contact on diagonally opposite sides of the worm tooth are obtained. The load carrying capacity and service life or durability of the drive are both considerably reduced.

Here is the joker in this combination. Because the worm gear, in the design under consideration, had a small number of teeth and these were generated with a 14½ deg pressure angle hob, it was badly undercut. This condition resulted in poor tooth action. Actually, in such designs, the worm addendum could be materially shortened without affecting contact ratio.

Since the tips of the worm threads function in areas where the involute profiles of the gear have been cut away by the generating hob, no tooth action can occur beyond the point of interference as shown in Fig. 3 by the shaded area. It is desirable, therefore, to remove the surplus metal from the tips of the worm threads, because by so doing, the danger of interference with a high fillet in the trochoid of the gear is avoided.

The argument that low pressure angles are preferred when backlash is critical, breaks down completely in an application of this kind, because the designer had provided an artificial means of removing backlash by a split gear construction. Removal of the ineffective worm material would have helped to obtain smoother action. It

is apparent that a higher pressure angle, such as 20 deg was indicated in this gear set. Undercut in the gear would then have been avoided.

A second fallacy, with the particular worm gear set, was the fantastic angular transmission tolerances that were originally specified. Even admitting that the extremely close tolerances specified could have been satisfied by one means or another, much of the accuracy is destroyed in a construction such as shown in Fig. 3, when the conjugate sections of the two halves are changed to remove backlash.

A much better way of removing backlash in worm gearing, in which retained accuracy is important, is by means of dual lead worms as used by the Gould & Eberhardt Company in their hobbing machines. These worms are ground to a standard lead on one flank of the thread, and to a shorter lead on the opposite flank. The difference in the leads depends on the amount of adjustment required, and is affected by ratio, center distance, and pitch. Backlash is taken up by moving the worm along its axis. The hob used for producing the gear is a counterpart of the mating worm, that is, it is also ground with a dual lead. Conjugate tooth action is therefore assured regardless of the amount of backlash between the worm and gear.

A dual lead worm and gear combination employed in a precision gear cutting machine is shown in Fig. 4. Dual lead worms have also been used successfully in many mechanisms such as dividing heads and other devices where the control of motion and backlash is important.

Worm gearing of low lead angle and large diameter is preferred in motion drives. A worm gear for a motion drive is a mechanical filter. The larger it is and the more teeth it has, the less error will pass through it. The ideal motion drive-worm gear has: (1) A large number of teeth; (2) as large a diameter as the mechanism will permit; and (3) a mating single-thread worm of as low lead angle as is possible. Because of these requirements, such a drive has low efficiency as a power transmitting device. In fact, all the desirable factors that are important in an efficient power drive are to be avoided in a motion drive.

Like other types of filters, some errors do get by in a worm gear drive. Among the errors it cannot filter out are bearing errors. Excessive run-out in anti-friction bearings affects uniform angular motion of both the worm and gear. Thrust bearings used to control the end play of the worm can be disturbing if improperly designed and adjusted. Another type of disturbance that can pass through a worm drive is one that is in phase with either the rotation of the worm or gear, or both.

A gear train for a machine commonly used to hob instruments gears is shown in Fig. 5. The manufacturer of this machine, like other manufactureres of gear generating equipment, stresses precision at the key points of the gear train that are enclosed in circles in Fig. 5. These key points center around the worm drives and lead screw. The index-worm gearing, feed gearing, and lead screw are made to a much higher degree of accuracy than the remainder of the gear train.

In the precision machine built by this manufacturer, extreme care is taken to produce the index-worm drive to a high degree of accuracy. The worm wheel is several times larger in the precision machine than the one in their standard machine. Also the wheel operates with a single-thread worm in the precision machine instead of a triple-thread worm that is used in their standard high production machine.

The remainder of the gear train is not comparable accuracy-wise, to that of the key points. The change gears, for instance, are made of unhardened steel cut to a commercial tolerance.

This practice of stressing accuracy at vital points is generally followed by machine tool builders. There are some exceptions; precision ground change gears are frequently employed in thread grinders, precision boring machines, and some bevel gear generating machines.

Whenever they are faced with a worm gearing problem, instrument gear designers would do well to follow the well-established practice of the machine-tool builders.

Many instrument gear trains employ bevel gears that cannot be mounted accurately. In Fig. 6 are shown two examples of instrument bevel gearing in which the locating surfaces cannot be accurately established in assembly. Note that there is a gap between the end of the gear hub, which is used as the mounting surface in cutting the gear, and the anti-friction bearing in the housing casting. These gears can be assembled only by bringing the teeth in mesh with each other, and observing the matching of the back angles. This practice is followed by many instrument manufacturers. It leaves much to be desired.

All tooth elements of bevel gears with intersecting axes (in which category fall all but hypoid gears) converge at the cone center as shown in Fig. 7. At this point, the pitch, the pressure angle, and the shaft angle are zero. All measurements start at this point. At a certain distance away from the cone center, a given pitch and pitch diameter are established to suit a given ratio. If the apex of the two pitch cones of a pair of gears do not coincide at the pitch center, conjugate action is destroyed. The results are as disastrous as those obtained when two spur gears of different pitch and

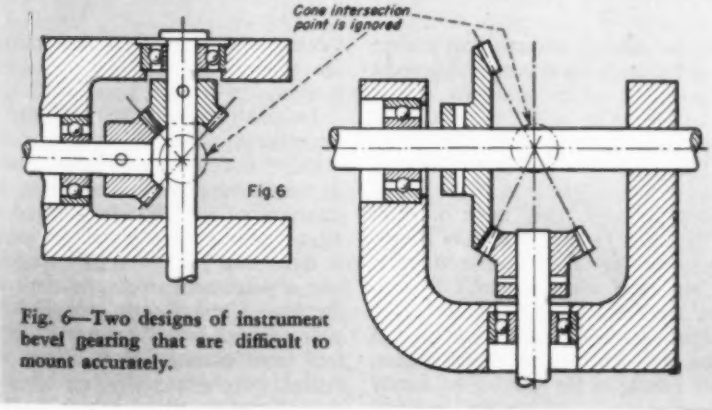


Fig. 6—Two designs of instrument bevel gearing that are difficult to mount accurately.

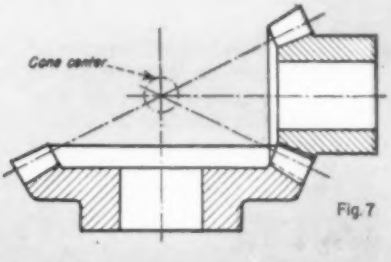


Fig. 7—In bevel gears with intersecting axes, all tooth elements converge at the cone center from which all tooth measurements originate.

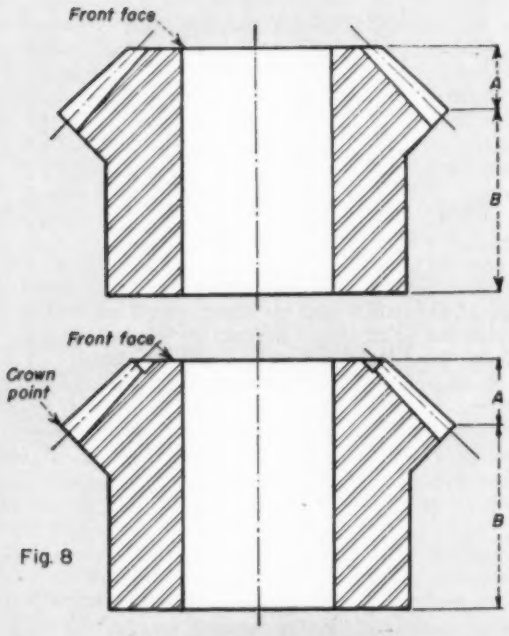


Fig. 8

Fig. 8—Bevel gear blanks with flat front faces facilitate accurate assembly. Distances A and B can be held closely, therefore, the front face can be used as a reference surface in assembly.

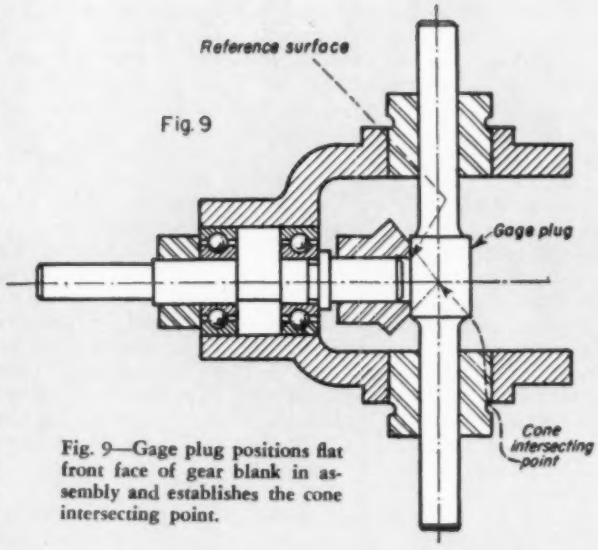


Fig. 9

Fig. 9—Gage plug positions flat front face of gear blank in assembly and establishes the cone intersecting point.

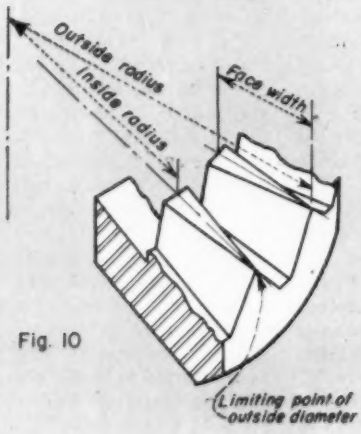


Fig. 10

Fig. 10—Diameter at which teeth become pointed generally limits the outside diameter of face gear.

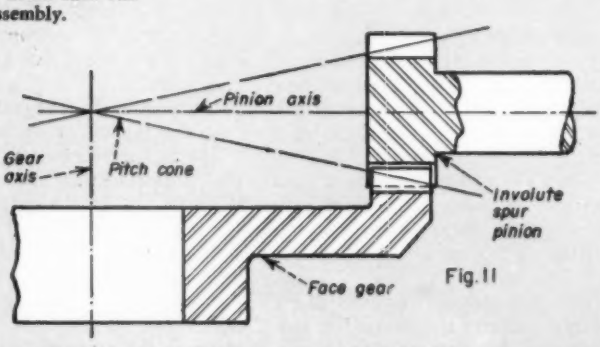


Fig. 11

Fig. 11—Section of an on-center face gear and pinion. Face width is usually narrower than a bevel gear of the same pitch and ratio.

pressure angle are meshed together.

The tolerance on back angles in bevel gears is quite liberal (see "Fine Pitch Bevel Gear Standard, ASA B6.8-1950) and in many instances bevel gears do not have back angles. One cannot be sure, therefore, when matching back angles that the gears are properly meshed.

One practical way to obtain correct mesh is to make the blanks with a flat front face as shown in Fig. 8. In machining the blank, the front face can be held to a close dimension both in respect to the crown point and the end of hub. The front face can, therefore, be used as a measuring surface to establish the cone intersecting point in assembly, which as shown in Fig. 9 can readily be done by means of a gage plug.

The majority of instruments employ straight bevel gears in right angle drives, although other types of gears of the bevel family have many advantages. Among the less common types, the virtues of which are not fully utilized, are Zerol gears.

Zerol gears are curved-tooth bevel gears with zero degree spiral angles. They belong to the spiral-bevel family of gears, and combine the localized tooth contact of spiral-bevel gears with the freedom from thrust controlling problems of straight bevel gears.

Localized tooth contact results in smoothness of motion and quiet operation; it also permits some latitude in misalignment. In instruments, because of boring difficulties and lack of rigidity of mounting, it is an advantage to have some provision for compensation of alignment errors and shaft deflections. Until recently, straight bevel gears did not have the virtue of localized tooth bearing. Some of the new straight bevel gear machinery can produce Coneflex gears, which have a

localized bearing like that obtained in spiral bevels and Zerols.

It would seem, therefore, that Zerol gears might be passing out of the picture with the introduction of the new straight bevel gears. This is not so. The practical consideration that should not be overlooked is one of machine tool investment. Zerol gears can be cut on the same equipment used for cutting all other types of spiral-bevel gears. On the other hand, a machine for cutting straight bevels cannot be used for other bevel gear types, and would not fit in the peace-time gear cutting equipment picture. Few straight bevels are used in consumer goods. Many instrument manufacturers, therefore, are reluctant to buy equipment that will not fit in with their peacetime manufacturing requirements.

It is suspected that the inertia on the part of instrument designers in not specifying more Zerol gearing, stems from two sources: (1) Lack of understanding, and (2) the fact that the blank design is wedded to the tools used to cut the teeth. Someday, serious consideration will be given to the problem of simplifying blank design for bevel gears of the spiral family.

Face gears are finding more and more acceptance in instrument design for right angle drives. Face gears, both the on-center and the off-center types, can be made with either spur or helical teeth. (See "Face Gear Design Factors", PRODUCT ENGINEERING, July 1950, p 117). Face gears belong to the bevel gear family of angular drives. Like bevel gears, the quality range is quite broad and covers the gamut of hobbed or milled face gears (which are not conjugate of a mating pinion at all) to the well made gears generated with a reciprocating pinion shaped cutter that is a facsimile of the mating pinion.

The American Gear Manufacturers Association is currently working on a standard for on-center face gears. This type warrants a brief discussion here, because of their advantages when applied in instrument drives.

RECOMMENDED USE. Face gears are generally recommended for application where the loads are relatively light and where the mounting difficulties prevent the establishing of accurate registering surfaces for the pinion. This flexibility in mounting results from the fact that a displacement of the pinion along its axis does not affect the conjugate action of the gear mesh. A change in the axial position of the face gear results only in a change in backlash, bearing pattern, and if extreme, a reduction in the smoothness of operation. In most applications, a small change in the axial position of the face gear is not serious.

DESCRIPTION. A face gear drive, as covered in the forthcoming standard, consists of an involute spur pinion that meshes with a gear having a tooth form that has been generated by a reciprocating cutter of substantially the same size and tooth form as the mating pinion.

The geometry of face gears can be summarized as follows:

The pitch surfaces of such a drive are cones. The momentary pressure angle is zero at the diameter on the face gear where the pinion pitch cone radius is equal to the pinion base circle radius. The momentary pressure angle increases in value for each increase in radius on the face gear. It becomes equal to the nominal pressure angle of the pinion at a distance from the center of the face gear where the radius of the pitch cone of the pinion is equal to the nominal pitch radius of the involute spur gear.

Not much of the portion of the tooth that lies inside of the nominal pitch diameter of the face gear is effective, because the trochoidal fillet produced by the tip of the cutter removes most of the active profile of the inside end of the tooth.

The outside diameter of the face gear, as shown in Fig. 10, is generally limited to that diameter where the teeth become pointed or to a diameter slightly beyond the points.

The tooth form of the face gear may be approximated by a series of racks of varying circular pitch and pressure angle. In Fig. 11 is shown a section of a face gear and pinion. The advantages of face gear drives are: (1) The latitude available in positioning the pinion across the gear face results in simple casting construction and mountings: (2) the pinion can be shaved to a high degree of accuracy; (3) the pinion can be cut on generally available spur gear cutting equipment.

The limitations of face gear drives center around the cutter diameter, ratio and capacity of currently available generating equipment. The new AGMA standard sets a minimum ratio limit at 1.5:1, and a maximum ratio limit at 30:1. The face width is usually narrower than that of a bevel gear of the same pitch and ratio. For this reason, face gears have a lower load carrying capacity.

Like spiral bevel gears, face gears are wedded to their gear cutting tools. The cutter should, for the best results, be exactly the same size as the mating pinion. Since a shank cutter of limited rigidity generates the face gear teeth, a limit of approximately 0.300 in. is placed on minimum cutter diameter. This cutter diameter restriction has an effect on ratio in ultra fine pitches.

In looking over gear trains, it will be seen that there are gears, gears and gears. Only when their combinations are put together so as to achieve the best functional performance at the lowest cost, is optimum selection achieved.

* * * *

AN EXHIBITION OF MODEL MACHINES made from the drawings of Leonardo da Vinci—15th Century artist and engineer—was presented by the International Business Machines Corporation, Sept. 25 to Oct. 4 in their New York offices. The working models, built by Roberto A. Guatilli and assistants, demonstrate how clearly Leonardo understood the engineering principles that have more recently been put into common practice. His three-speed drive with its squirrel cage pinion, preceded our standard automobile transmission by about 400 years, and the principle of his cone-headed mitre valve is used in the check valves of nearly all our pumps and hydraulic systems.

Other displays included a wagon with a roller-bearing mounted shaft, hand powered machine tool for grinding lenses, and military machines.

* * * *

CONTRARY TO COMMON BELIEF the first iron vessel was neither the *Monitor* nor the *Merrimac*, but the *John Randolph* which was built in 1834 by John Caut. The plates were manufactured in Berkenhead, England, and shipped to Savannah, Ga. where they were riveted together. This 122 ton vessel was owned and operated from Savannah.

* * * *

MANY EXPERTS CONSIDER the late Dr. Robert H. Goddard of Clark University as the father of modern rocket propulsion. He developed and tested the first successful liquid fuel rocket in 1926, and was the first to fire a rocket missile at supersonic speed.

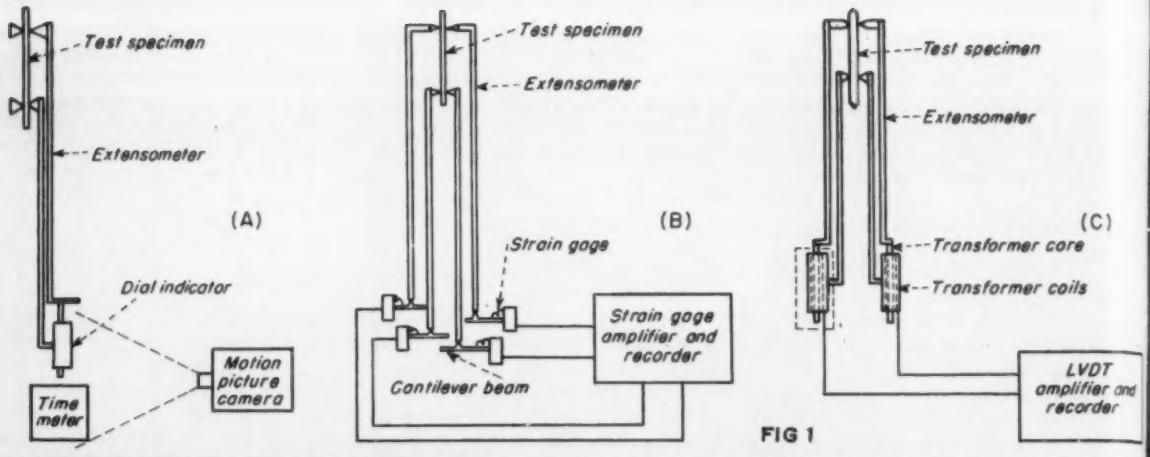


FIG 1

Fig. 1—Three types of creep measuring and recording systems: (A) dial indicator system; (B) cantilever strain gage system; and (C) system utilizing linear variable differential transformers. The *LVDT* system is fast, accurate, and gives a visual indication of conditions as the test progresses. Fig. 2—Extensonmeter system utilizing linear variable differ-

An Improved Creep Measuring and Recording

SEVERAL DIFFERENT TYPES of short time creep measuring and recording systems are currently being used by industry. Among these is a dial indicator system, Fig. 1(*A*), in which a dial indicator extensometer and a running time meter are photographed with a 16 mm motion picture camera.[1] Another system, which was developed by the Cornell Aeronautical Laboratory,[2] consists of a cantilever type strain gage and suitable amplifiers and recorders, Fig. 1(*B*), to mechanically measure and electrically indicate the amount and rate of creep.

Both of these methods of measurement have several serious disadvantages. With the dial indicator system, the data cannot readily be read as the test progresses, with the result that malfunctioning of the equipment may be detected too late for correction. The strain gage system requires a complex electrical circuit and has a limited range of sensitivity. This system is easily damaged.

The use of a system consisting of linear variable differential transformers (*LVDT*) to measure creep, and a modified potentiometer recorder to chart it, eliminates such problems. In brief, the *LVDT* method has the following advantages over established methods:

1. *It has the required accuracy, reliability, and simplicity of operation.* Although there are no data affording a direct comparison, the *LVDT* system should be more accurate than the dial indicator system during the early stages of creep in tests of sheet material. Erratic strain readings are often given by a dial extensometer when load is first applied to a specimen and during the early part of a test. Apparently, this result is due to a straightening of a bend in the test specimen.

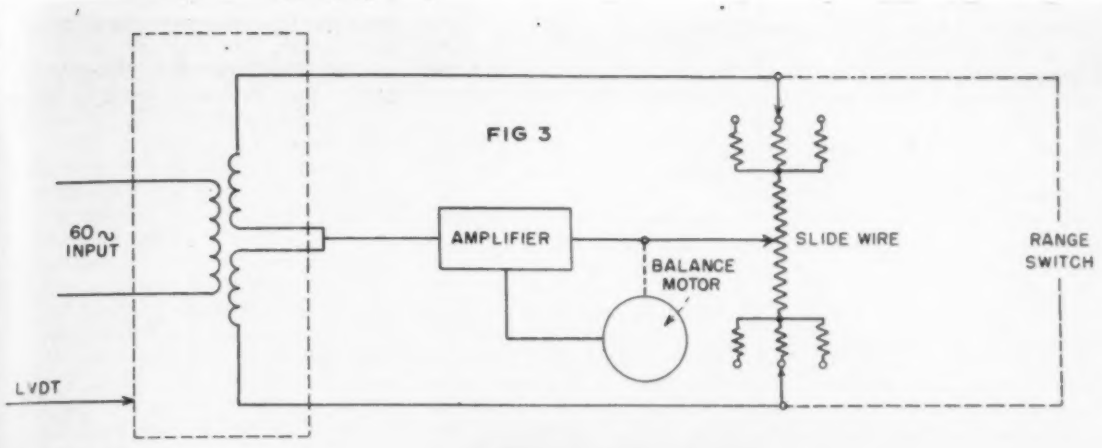
No such difficulties have been experienced with the *LVDT* system, since two differential transformers are used, Fig. 1(*C*), one on each side of the specimen. Straightening of the specimen causes equal and opposite movements in the differential transformers on opposite sides, and the net resultant is zero.

Also, the ability of the *LVDT* system to average strain from two sides of a specimen makes this system more suitable for creep test of bar material, in which non-axial loading and unequal straining are frequently encountered.

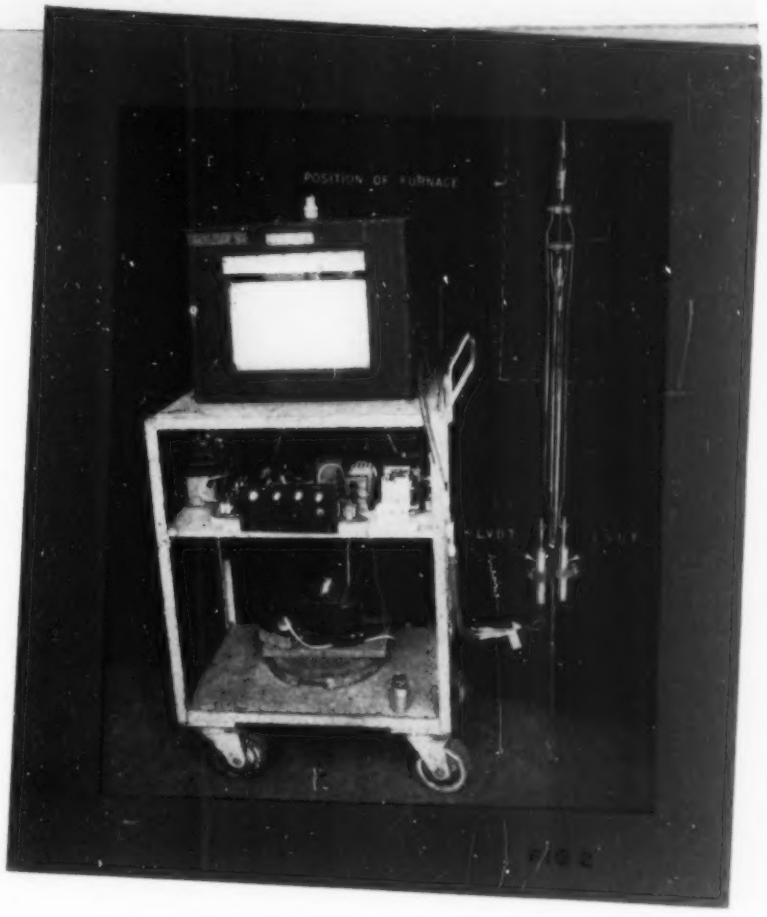
2. *Since the progress of each test is visually recorded, corrections in test conditions can be made as the test progresses, and lost time from re-runs is thereby minimized.*

3. *Use of the LVDT system requires less man hours than the dial indicator system.* The time saved in the transcription of data may amount to about 30 minutes of operator time per test for short tests.

4. *An LVDT recording system is applicable to other types of research and testing problems.* Differential transformers are generally useful as a means for measuring small movements (see PRODUCT ENGINEERING, July 1950) and the *LVDT* system can be



ential transformers to obtain creep data from a sheet specimen. Fig. 3—Basic *LVDT* circuit for one channel and three ranges.



J. W. HUFFMAN
Engineering Research Laboratory
North American Aviation, Inc.

System

used as a general purpose instrument to record data from other types of tests, e.g. the deflection of structural members under load.

Construction of System

An extensometer system utilizing differential transformers as set up for use with one creep machine is shown in Fig. 2. The test specimen is of conventional shape. Two pairs of extensometer arms transfer elongation of the specimen to two linear variable differential transformers. These transformers consist essentially of three coaxial coils wound consecutively on a phenolic cylinder with an axial hole. A steel slug is inserted in this hole. When the center (primary) coil is energized with a-c voltage, a-c voltages are induced in the two end (secondary) coils. The sum of the two secondary voltages is constant. Relative axial movement of the slug, however, reduces the voltage in one secondary coil and increases it in the other. The voltage in each coil is a linear function of the slug position. The difference in voltage between the primary coils causes an unbalance in the potentiometer circuit of the recording system.

Movement of the potentiometer slidewire to restore balance in the circuit moves the pen of the recorder, thereby indicating and recording the elongation of the test specimen. One differential transformer is suspended from each side of the test specimen so that strain from both sides is sensed and electrically averaged.

Strain and time are recorded simultaneously by data points printed on a continuous roll moving at a constant rate. The recorder is equipped with a range switching device in order to obtain both maximum resolution and maximum range. Details of the electrical system are shown in Fig. 3 above.

In operation, a test may be begun with the recorder in the most sensitive range. When the specimen has elongated to the end of this range, the printing carriage actuates a switch that changes the ranges of the recorder to the next higher range. This process continues until the specimen ruptures or the end of the last range is reached. The choice of scale ranges is arbitrary.

Operation of the System

Several creep tests were conducted with the *LVDT* unit to determine its accuracy and general operating characteristics. In these tests, creep data given by the recorder were checked against measurements made directly on the test specimens with a cathetometer, which is a length measuring instrument consisting of a telescope that moves along a finely graduated scale.

The results of these calibrations are tabulated in Table I. Comparison is made between percentages rather than between elongations, since different gage lengths were used in the two methods.

The relation between the *LVDT* measurements and the cathetometer measurements is shown by a plot in Fig. 4. Except for the point *"P"*, the data points fall closely about the solid line representing perfect agreement between the two methods of measurement. The point *"P"* is believed to be displaced because of some equipment malfunction. If the scatter of the data lies between the dotted lines, as seems probable, the precision of the *LVDT* is, at present, more than adequate for tests of sheet material. However, greater precision will probably be achieved by improvements in the electrical circuit of the system.

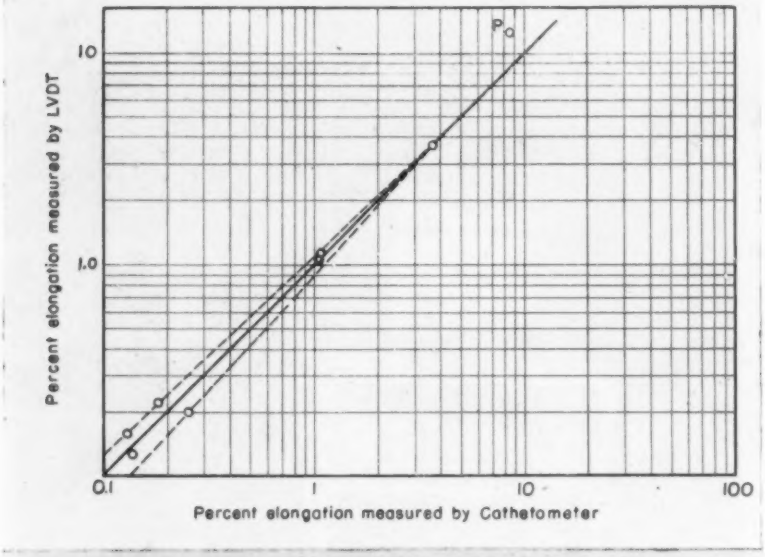


Fig. 4—Comparison of results from LVDT system with measurements of elongation made directly on the specimen with a cathetometer.

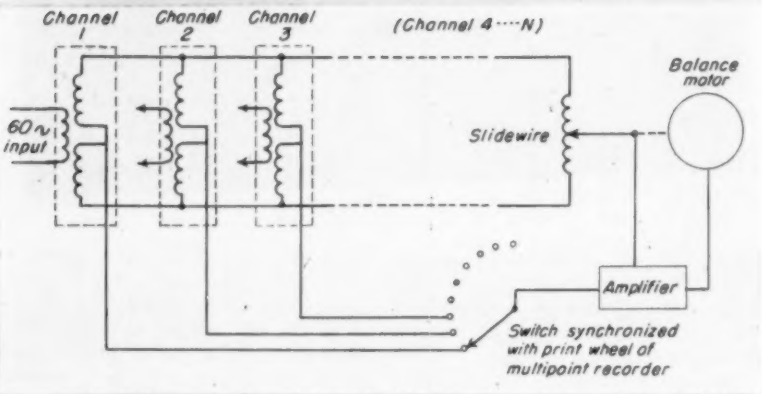


Fig. 5—Basic multi-channel circuit for bank of creep testing machines. In addition, a separate range switching device must be used for each creep machine.

The time required to start a creep test was found to be about the same for the *LVDT* and dial indicator systems. A comparison of the times required to transcribe data for the two systems is complicated by the fact that the time varies with the length of test, particularly with the dial indicator system. For long tests, the time for transcribing is approximately the same for the two systems. For short tests, the data from the recorder chart may be read in a few seconds; short tests with the dial indicator require that the film from the recording cameras be developed and viewed with a Recordak, an operation consuming 15 to 30 minutes.

Maintenance and service required by the two systems are comparable. The *LVDT* system requires little or no attention during operation. Maintenance consists principally of periodically checking the chart paper and the amplifier tubes of the recorder.

An *LVDT* system for a bank of creep machines can be developed by using a multi-point recorder to record in sequence the data from each machine. A basic circuit for a number of channels is shown in Fig. 5. Such an arrangement would necessitate the installation of a range switching device (not shown) for each creep machine.

Table I—Calibration of Linear Variable Differential Transformer with Cathetometer

Specimen No.	Temp., F	Elongation, Percent	
		By Cathetometer	By *LVDT*
1	900	1.13	1.18
2	75	0.265	0.20
3	75	0.182	0.217
4	75	0.154	0.142
5	75	1.11	1.12
6	75	8.75	10.30
7	800	0.125	0.167
8	900	3.77	3.69

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2. Guarneri, G. and J. Miller, "A Cantilever Strain Gage for High Temperature Tensile and Creep Testing of Sheet Materials", Cornell Aeronautical Laboratory, Feb. 1, 1948.

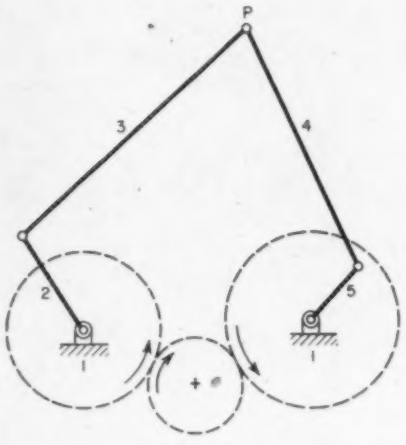

Fig. 1—General case of the five-bar linkage. An infinite number of different motions can be generated by varying linkage characteristics. The authors discuss one special case.

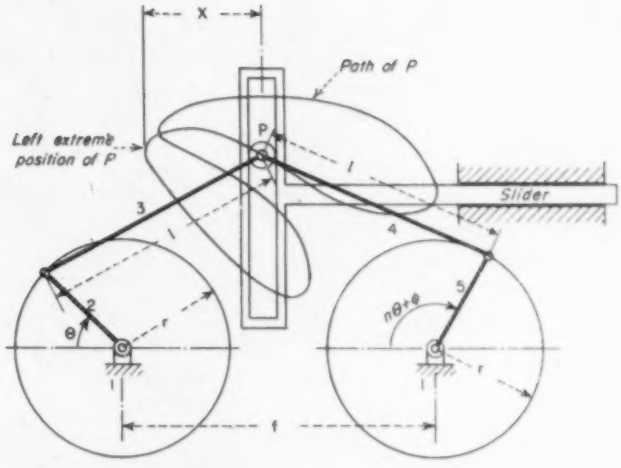

Fig. 2—Path of point P is shown for this special case—a symmetrical, five-bar, double crank linkage. Slider will have two forward and two backward strokes for this mechanism because crank speed ratio is 2. A phase angle of 30 degrees was chosen for illustration purposes.

Analysis of a Symmetrical Five-Bar Linkage

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SUCCESS IN THE DESIGN of mechanisms depends, first of all, upon a familiarity with many types of linkages and an appreciation of their possibilities and limitations. Although the slider crank and the four-bar linkages can generate a great variety of motions, there are many situations which these simple linkages cannot handle unless they are used in complex combinations. In these cases, other types of linkages that are better suited for the job should be investigated.

One type whose possibilities have not been fully explored is the five-bar, double-crank linkage shown in Fig. 1. In this linkage, gears maintain a specified phase angle between the two cranks to make a mechanism from the combination. As the cranks rotate at a constant angular velocity, point P traces a path whose characteristics are determined by the lengths of the links, the speed ratio of the cranks, $\frac{\omega_5}{\omega_2}$, and the value of the phase angle. It is impossible to describe and tabulate all of the motions that could be generated in this manner, but selected data on one special form of this linkage will indicate the possibilities of the linkage and will serve as a guide in selecting the linkage dimensions required to satisfy a particular problem.

The symmetrical five-bar linkage shown in Fig. 2. will be used for illustration. By symmetrical is meant that cranks 2 and 5 are of equal length and connecting rods 3 and 4 are also of equal length. Discussion also will be restricted to the case for which point P drives a slider whose motion is confined to a plane parallel to the line joining the crank pivots. The left crank angle, θ, is defined as positive when measured clockwise from the left end of the x-axis; the speed ratio of the cranks is called n, and the phase angle, ϕ, is the angle from the left end of the x-axis to crank 5 when θ is 0 degrees. It is positive when measured clockwise and negative when measured counter clockwise. The distance between the fixed crank pivots if called *f*.

In Fig. 3(A) are shown typical diagrams of the motions that can be produced by this linkage with different values of the speed ratio. The displacement "x" of the slider from its extreme left position has been plotted against the angular position of crank 2 for a single combination of linkage dimensions.

It can be seen from these curves that, in general, the number of strokes of the slider (total of forward and backward strokes) per complete revolution of crank 2 is twice the value of the speed ratio if this ratio

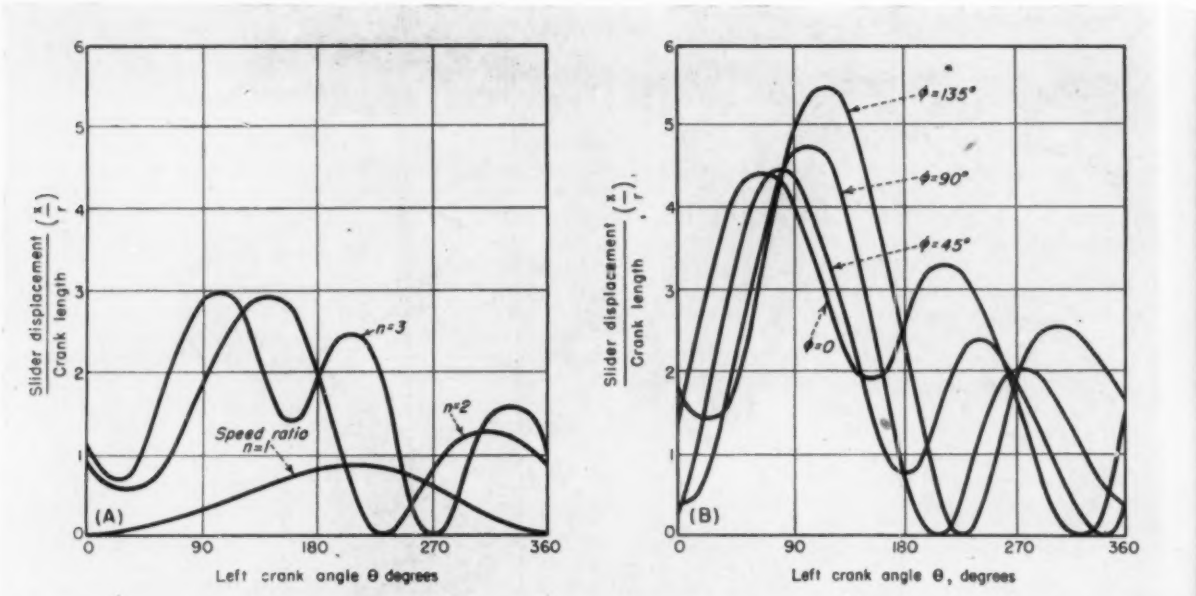


Fig. 3—(A) Number of slider strokes as well as their length and time relation can be varied by changing the speed ratio. (B) and (C) Varying the phase angle changes the shape of the curves and also displaces the troughs and

is a whole number, either positive or negative. Therefore, this type of linkage is useful when a periodic reciprocating motion consisting of several strokes of different lengths and different time relations is desired.

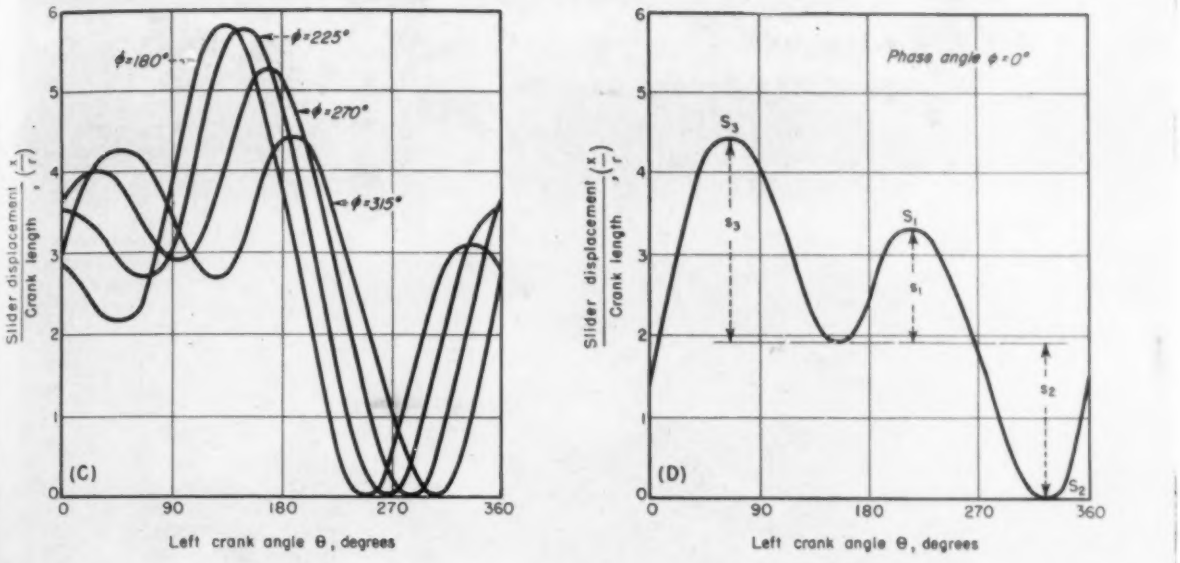
Probably the lowest speed ratios of practical significance are ± 2, since the motions produced with speed ratios of ± 1 can be approximated by simpler linkages, such as the offset slider crank. Fig. 3(B) and (C) shows a series of displacement diagrams for the slider motions produced by a symmetrical linkage with a crank speed ratio of $+2$. These curves have been drawn for one set of linkage dimensions but for a series of phase angles. Although all curves for this value of crank speed ratio have two crests and two troughs, as the phase angle increases the shapes of the curves change and the troughs and crests are displaced with respect to the starting position of crank 2. Further variations could be obtained by varying the linkage dimensions, even though the symmetrical characteristic is retained.

To incorporate the effects of all of these variables in a convenient source, design charts have been constructed for this symmetrical five-bar linkage and included as Reference Book Sheets, p. 201, 203 and 205, of this issue. The method used in constructing these charts is as follows:

Referring to Fig. 3(D), the first trough in the curve for $\phi = 0$ degrees is designated R, the first crest to the right of R is S_1, and the trough to the right of S_1 is S_2. The crest to the left of R (or to the right of S_2) is labeled S_3. The vertical distances from R to S_1, S_2 and S_3 are represented by s_1, s_2 and s_3, respectively. They are positive when measured upward from R and negative when measured downward. The location of R in terms of the angular position of crank 2 can be found from Fig. 3(B) and (C). When ϕ is zero degrees R occurs at 153 degrees of the left crank angle. When ϕ changes to 45, 90, 135, 180 . . ., the same trough R occurs at 184.5, 210, 231, 249, 270, 280 and 303 degrees respectively. When the phase angle is 360 degrees, R becomes S_2 and corresponds to 324 degrees of the left crank angle. Thus a continuous curve of the left crank angles at which R occurs can be plotted against the different phase angles. This curve is called R in the design charts. Similarly, the left crank angles at which S_1, S_2 and S_3 occur for different phase angles are curves S_1, S_2 and S_3 in the design charts. To make these curves continuous, sometimes it is necessary to measure the crank angle in negative values i.e. counter clockwise from the left end of the x-axis. For example, S_1 in Fig. 3(D) occurs at -144 degrees which is the same as $+216$ degrees if measured clockwise.

Another set of curves in the design charts compares the lengths of the different strokes and also compares stroke lengths to linkage dimensions

The plot $\frac{s_1}{2r}$ vs. phase angle ϕ, shows the length of the first forward stroke as compared with the diameter of the crank circle. In the first backward stroke, i.e. the distance between S_1 and S_2, $s_1 - s_2$, can be represented by the curve $\frac{s_1 - s_2}{s_1}$ vs. phase angle. This curve shows the length of the first backward stroke as compared with the first forward stroke. Also, the curve $\frac{s_3 - s_2}{s_1}$ vs. phase angle shows the length of the second forward stroke as compared with the first forward stroke. The point of intersection of the curves $\frac{s_3 - s_2}{s_1}$ and $\frac{s_1 - s_2}{s_1}$ indicates $s_1 = s_3$ and its corresponding phase angle, and crank angles can be read directly from the design charts. As indicated previously, $\frac{s_1}{2r}$ for $\phi = 360$ deg. is the same as



crests. These curves are drawn for a ± 2 crank ratio. Linkage dimensions correspond to l/r of 9 and f/r of 6.

(D) Notation used in construction of design charts is illustrated in the above drawing.

$\frac{s_3 - s_2}{2r}$ for $\phi = 0$, $\frac{s_1 - s_2}{s_1}$ for $\phi = 360$ is the same as $\frac{s_3}{s_3 - s_2}$ for $\phi = 0$, and $\frac{s_3 - s_2}{s_1}$ for $\phi = 360$ is the same as $\frac{s_1}{s_3 - s_2}$ for $\phi = 0$, so that the stroke curves are continuous.

Sample Design Problem

To illustrate the use of the design charts consider the following problem. A reciprocating motion is required for which the slider moves forward with a 9 in. stroke, reverses and moves backward at least 4½ in., forward again to within 3 ± 0.1 in. of the position at the end of the first forward stroke, then backward to its initial position. The time between the two extreme forward positions is to be ⅜ of the time for the complete cycle, i.e. 135 degrees of the left crank angle. A tolerance of ± 3 degrees on this angle is alowed.

Expressing this problem in the notations used in the design charts,

$s_1 = 9$ in.

$s_1 - s_3 = 3 \pm 0.1$ in.

$\frac{s_1 - s_2}{s_1} > 1\frac{1}{2}$

$$\frac{s_1 - s_3}{s_1} = \frac{s_1 - s_2}{s_1} - \frac{s_3 - s_2}{s_1}$$
$$= 0.33 \pm 0.01$$

To find a linkage that can generate such a reciprocating motion, a value of the phase angle ϕ must be selected from the design charts that will satisfy the following three conditions:

(1) The corresponding difference in ordinates between the curves $\frac{s_1 - s_2}{s_1}$ and $\frac{s_3 - s_2}{s_1}$ in the design charts is 0.33 ±0.01

(2) The corresponding value of $\frac{s_1 - s_2}{s_1}$ is greater than ½

(3) The corresponding difference in ordinates between the curves S_3 and S_1 is 135 ± 3 degrees.

As shown in Table I, several of the linkages, for which design charts have been included, can generate the desired motion. It remains for the designer to select the one that is best adapted to the physical and structural requirements of his machine.

If a desired reciprocating motion consists of two forward and two backward strokes in a complete cycle but cannot be generated by a symmetrical five-bar linkage, including those for which charts have not been included, then a possible procedure is to select a symmetrical linkage which approximates the desired motion and modify it by cut-and trial methods. The modification can involve one or more of the following:

(1) Making the linkage non-symmetrical.

(2) Setting the slider at an angle with the fixed pivots.

(3) Using a connecting rod between point P and the slider.

Table I—Data for Five-Bar Linkages Shown on Pages 201, 203 and 205

Linkage ($\Omega = +2$)	Phase Angle	$S_1 - S_3$	$\frac{s_1 - s_3}{s_1}$	$\frac{s_1 - s_2}{s_1}$	$\frac{s_1}{2r}$
$l/r = 5$ $f/r = 4$	119	133	0.34	0.64	2.08
7 4	140	137	0.34	0.62	2.88
9 4	154	138	0.33	0.60	3.66
5 5	99	133	0.34	0.63	1.68
7 5	127	136	0.34	0.60	2.31
5 6	65	137	0.34	0.66	1.42

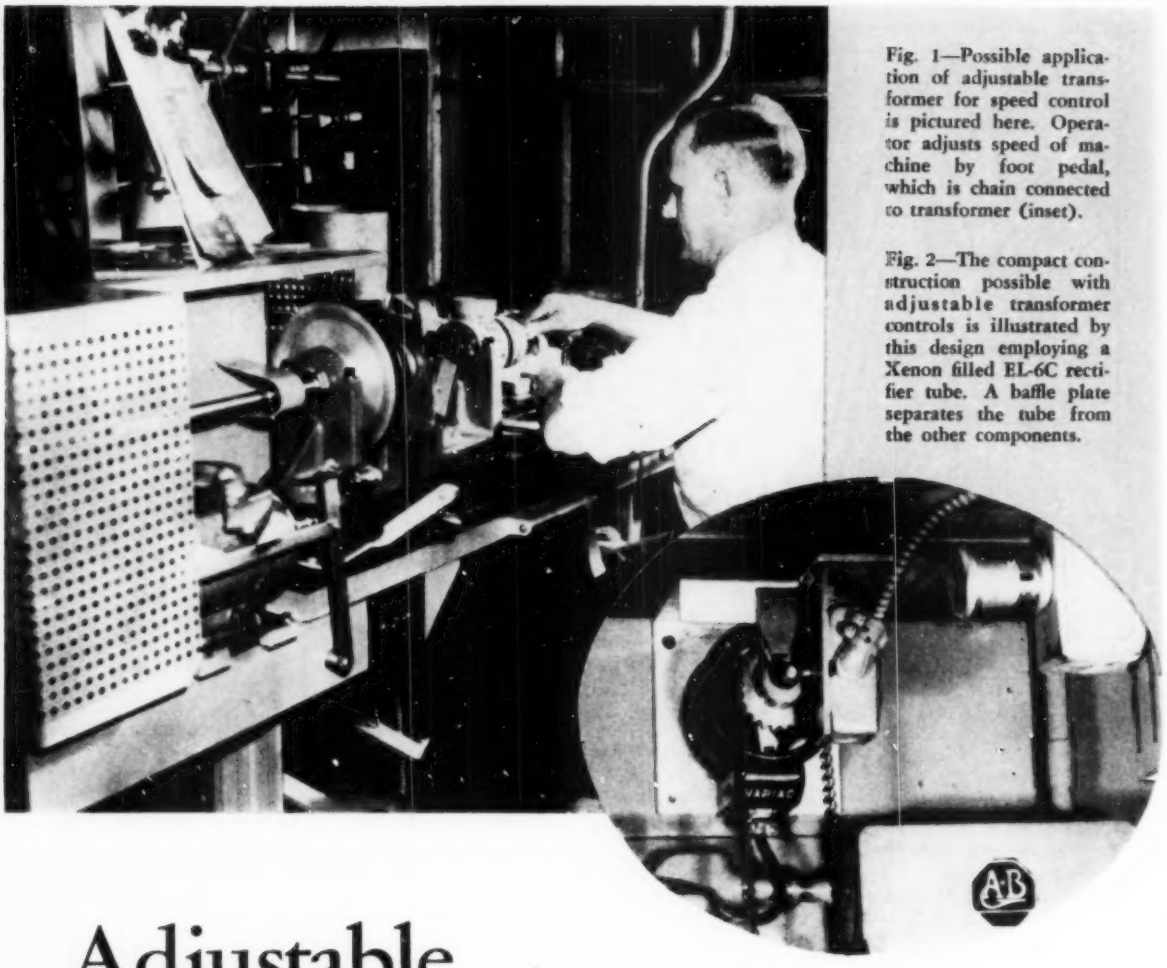


Fig. 1—Possible application of adjustable transformer for speed control is pictured here. Operator adjusts speed of machine by foot pedal, which is chain connected to transformer (inset).

Fig. 2—The compact construction possible with adjustable transformer controls is illustrated by this design employing a Xenon filled EL-6C rectifier tube. A baffle plate separates the tube from the other components.

Adjustable Transformer Motor Speed

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ADJUSTABLE TRANSFORMER motor speed controls are being applied in increasing numbers on production equipment. This trend has resulted partly from the evolution of the adjustable transformer from a laboratory device to a piece of industrial equipment capable of handling considerable power, and partly from the development of suitable circuits and tube and dry plate rectifiers so that the controls can be used with d-c shunt or compound motors.

The characteristics of an a-c motor operated directly from an adjustable transformer are suitable for only a limited number of applications. Series and repulsion motors can be controlled over a wide range of speed, but speed is highly sensitive to changes in load. The combination of an adjustable voltage control with a motor of this kind is satisfactory only when the load is constant or varies in a suitable manner with speed, as in the case of a ventilating fan. But even when the driven load is constant, considerable variation in speed can be caused by heating of the lubricants, working in of the bearing surfaces and so on. In general, therefore, transformer controlled a-c motors are not used often for machine tool drives and similar applications requiring good adjustable speed characteristics.

It is in the field of d-c motors that the adjustable transformer is finding wide acceptance. When combined with a rectifier, this device provides an adjustable voltage that can be applied to the armature of a d-c shunt or compound motor operating with constant field excitation. The inherently good regulation characteristics of the motors are preserved and a simple control is made available.

An arrangement of this kind is basically a constant speed system, because the variation of speed with load is due only to the *IR* drop in the armature voltage source, modified somewhat by the change in flux due to armature reaction and the series field, if used. Because of the good regulation of the adjustable transformer and because the conduction point of the rectifiers is not held back by grid control, the

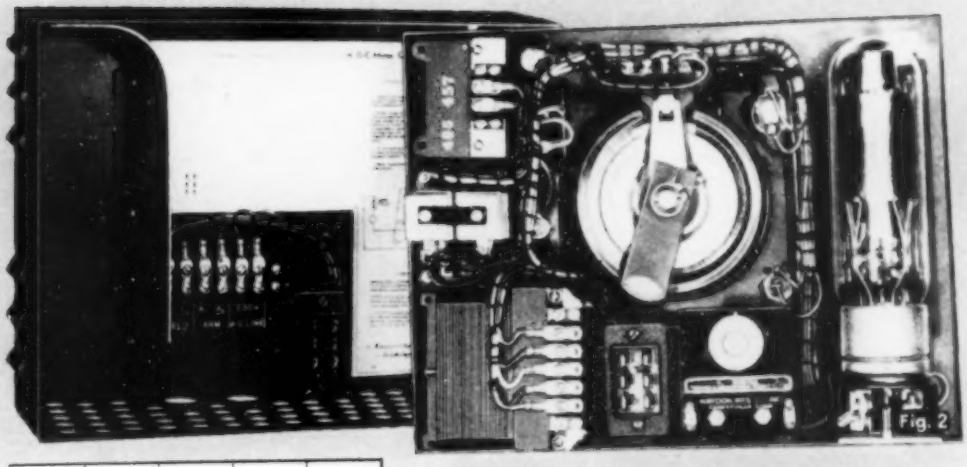


Fig. 2

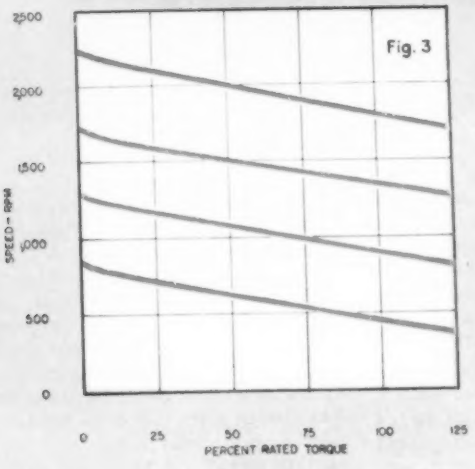


Fig. 3—Speed-torque curves for 1/3 hp adjustable transformer control and compound wound motor. Percentage regulation varies inversely as the full load speed setting.

Table I—Regulation of Adjustable Voltage Motor Control

Rating, hp.	Type Rectifier	Type Motor	Supply Voltage	Motor Speed, rpm.	Regulation	Supply Resist, ohms.
1/15	Selenium	Shunt	115	1725	27%	13.3
1/15	Selenium	Universal**		3450*		
1/3	Tube E1-6C	Shunt	115	8800	7%	10.6
1/3	Selenium	Compound	230	1725	16%	15.8
3/4	Selenium	Compound	115	1725	24%	3.8
1-1/2	Selenium	Compound	230	1725	24%	1.9
						4.4

*High-Speed range obtained by field weakening.
**Reconnected for operation of field at constant 10 volts.

Controls

internal resistance of the armature voltage source is about half the armature resistance, so that the speed regulation of the motor is usually between 60 and 75 percent of the total speed regulation of the control and motor.

When diodes or selenium rectifiers are employed in a rectifier system, it is possible to obtain both good regulation and good form factor by using only a small choke. In a thyratron rectifier, on the other hand, this is not the case.[1]

In the commercial thyratron speed controls the poor form factor is accepted and a motor about 50 percent oversize is used to handle the increased dissipation. Compensating circuits are used to improve the regulation.

The autotransformer control gives somewhat poorer regulation than is obtained with the compensated thyratron control. But since it supplies almost pure d-c to the motor armature, there are no torque pulsations and motors can be used substantially at their full ratings.

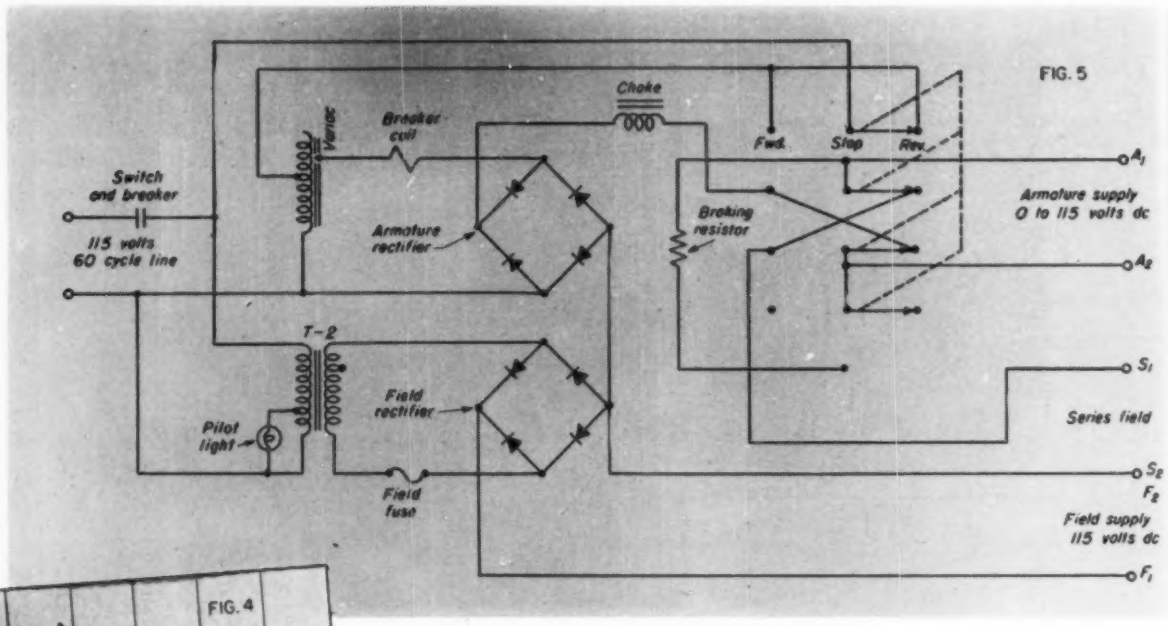
Performance Characteristics

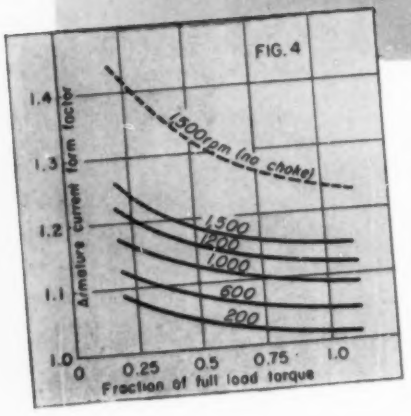
Regulation. As has been noted, the regulation of an adjustable voltage system is essentially that of the shunt- or compound-wound motor that is used, increased somewhat by the regulation of the armature supply. Two commercial models of the control rated at $\frac{1}{3}$ and $\frac{3}{4}$ hp respectively, have 24 percent regulation at base speed when used with compound-wound motors and selenium rectifiers. If the series field is cut out so that a straight shunt motor connection is employed, the regulation drops to about 18 percent. The series field is preferred, however, because of its improved starting characteristics.

In another model of the $\frac{1}{3}$ hp control, which makes use of a tube rectifier, the regulation is 16 percent for the shunt connection—reflecting the slightly lower resistance of the tube rectifier.

The above values of regulation are typical, but greater variation will be found with motors of lower rating. A smaller selenium-rectifier control of 1/15 hp rating gives a regulation of 27 percent with a 1,725 rpm 1/15 hp

[1] *W. P. Overbeck, "Critical Inductance and Control Rectifiers", Proc. I.R.E. V. 27, pp. 655-659, October 1939.*





shunt motor at base speed, and 20 percent when the motor is operated at twice base speed by field weakening. On the other hand an 8,800 rpm, 1/15 hp shunt motor, made by converting a series motor and operating the field at a constant value of 10 v, was found to have a regulation of only 7 percent. These results are summarized in Table I.

The percentage regulation figures just given apply only when the motor is operated at base speed. The regulation, expressed as rpm rise in speed between full-load and no-load, is approximately constant, meaning that the percentage regulation varies inversely as the full-load speed setting. This is illustrated in Fig. 3, which shows a family of speed-torque curves for a $\frac{1}{3}$ hp selenium rectifier control operating with a compound-wound motor. Almost identical curves apply to the larger $\frac{3}{4}$ hp control.

Even at the low-speed settings the regulation of the control and motor has proved satisfactory. It is becoming clear that although good regulation is desirable, percentage regulation should not be used blindly as a figure of merit in judging an adjustable-speed control. The regulation requirements should be matched to the work to be done, and experience is showing that extremely close regulation is required only for exceptional applications.

Form Factor and Motor Rating. The form factor of the armature current is the ratio of the rms current to the d-c value. Only the d-c component produces useful power output, the a-c component merely increasing the losses. Assuming that armature dissipation limits the current that can safely be drawn, the useful power that can be supplied by a given motor varies inversely as the form factor. One investigator gives the figure of 1.55 for the form factor in a thyratron control, the value being approximately constant over the speed range. Corresponding values for the autotransformer speed control are given in Fig. 4. Only the full-load value is important in limiting the output, and this varies from 1.16 at base speed down to 1.01 or 1.02 at the lower speed settings.

Speed Range. The speed of the motor, with most loads, is infinitely adjustable from base speed down to zero. It is relatively easy with a motor which is free from "cogging" to run a smooth or light load steadily at 20 or 30 rpm. Although the regulation is poor at low speeds, most loads can be gradually started or stopped.

High speed motors may be used to advantage with adjustable transformer speed controls, either to increase the maximum available speed or to obtain a wide working speed range. Shunt or compound-wound motors for speeds greater than 5,000 rpm are not generally available, so a universal motor reconnected to operate at constant field excitation is generally used. By this means equipment powered by a universal motor can be converted for adjustable constant-speed operation without changing the motor. The change gives improved regulation over a wide speed range, and while starting torque is reduced, any starting problems can be overcome by bringing up the speed with the control knob. When motors having base speeds of 10,000 rpm or higher are used, it is possible to control light loads over a speed range of several hundred to one.

The range of speed that can be covered by armature voltage control can, of course, be extended by varying the field excitation. The base speed of the usual compound-wound motors can be raised about 25 percent by field weakening. This range has been used in commercial adjustable-transformer controls to give greater flexibility in fixing the top speed when a control is installed, but not to increase the working range. A tap on the field transformer at 65 percent of normal voltage gives about 15 percent increase in the motor base speed. The desired tap is selected according to the application. Smaller motors of standard design permit an increase in base speed of up to 2:1 by field weakening.

Special motors can be controlled over a speed range of 4:1 by field control and even up to 8:1 by more elaborate constructions. Such motors

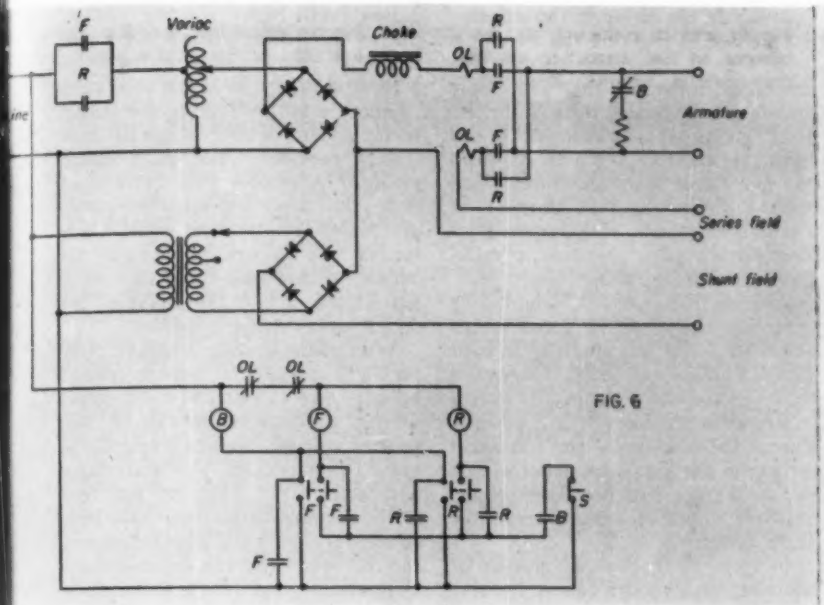


FIG. 6

Fig. 4—Armature current form factor at various speeds and loads. The reduction in form factor at low speed partly offsets the loss of efficiency of the motor cooling fan.

Fig. 5—Circuit for manually operated adjustable voltage control utilizing selenium rectifiers. See text for thorough discussion of circuit components and circuit operation.

Fig. 6—Control circuit for push button operation with dynamic braking. This circuit requires push buttons with two normally open circuits for starting and reversing and a single normally closed button for stopping.

are expensive and are designed for applications where the range of speed obtainable by field control is all that is required. Use of such motors with both field and armature control has seemed both complicated and expensive for applications which have been considered so far but an arrangement of this kind might be used to meet special requirements.

Other Characteristics. The low internal resistance of the armature supply means that full advantage can be taken of the excellent starting characteristics of compound motors. Selenium rectifiers have ample short-period overload capacity to take care of fast starting and reversing. Even when diode gas tube rectifiers are employed it is economical to furnish greater starting current capacity than is usual with the thyratron controls. Adjustable transformer controls have outstanding ability to start heavy loads quickly.

When heavy loads must be started at full voltage, the compound-wound motor is preferred to a straight shunt motor because the ratio of starting torque to starting current is considerably higher. Except with heavy loads, motors of $\frac{1}{3}$ hp and smaller present no starting problem, so that either type may be employed, the shunt motor giving slightly better regulation.

Design of Controls

Motors provided with a commutating pole give improved commutation over the working speed range, particularly in reversing service. This consideration appears to be of less importance with small motors, and sizes below $\frac{1}{4}$ hp are not generally available with commutating poles.

Either diode tube rectifiers or selenium rectifiers may be employed. Tube rectifiers are compact, have long life and can be operated in high ambient temperatures, but they require considerable filament power which may be difficult to dissipate in a compact control. Tube rectifiers, also, require some sort of time-delay mechanism to permit warmup before the load is applied, and a center-tapped autotransformer is necessary for the rectifier circuit.

A thermally operated bimetallic switch is frequently employed to provide the time delay but requires a relay in order to recycle quickly. A clock motor operated switch is more satisfactory, and, when the delay is a minute or less, requires no auxiliary relay. In this case the unit is designed so that the motor stalls when the switch is operated; a spring and clutch mechanism gives a quick reset when power is interrupted.

There are no critical requirements for the tubes. In a diode rectifier with a choke the peak to average current ratio is low because conduction continues for the full duration of each half-cycle. This makes it relatively easy to provide ample starting current capacity. Mercury, mercury-gas or gas-filled tubes can be used as desired according to the ambient temperature requirements of the intended service. Xenon-filled tubes can be operated over the wide temperature range of from —55 to +75 Centigrade.

Selenium rectifiers have the advantages of not requiring a time delay device or a center-tapped transformer. In addition selenium rectifiers have a large short-period overload capacity, so that in general no margin in current rating need be provided to take care of starting requirements. However, selenium rectifiers cannot be used in as high ambient temperatures as can tube rectifiers. When built into a control box, they must be put in the coolest location and provided with good ventilation.

Most of the present commercial selenium rectifiers have ratings based on a 35 C ambient temperature at the rectifier stack or 75 C maximum plate temperature. In a compact control in a 35 C ambient, the box rise will bring the stack ambient to about 50 C. The rated current at 50 C must be reduced to about 60 percent of the 35 C ambient value to avoid excessive plate temperature. A substantial loss in output thus results when a rectifier of this type must be used in a compact control.

Work is being done to develop stacks having a higher maximum plate temperature rating, which would result either in greater output at normal ambients or normal output at higher temperatures. One manufacturer now offers rectifiers designed for 100 C maximum plate temperature or 45 C ambient. Another manufacturer's approach to the problem is to offer stacks that will withstand occasional high temperatures without failure, although specifying the usual 35 C limit for maximum life. This supplier gives a life expectancy of 15,000 hr for a rectifier operated continuously at rated

voltage and current in an ambient temperature of 55 C, and of 40,000 hr or more in a 35 C ambient.

Circuit. A typical circuit for a manually operated selenium-rectifier control is shown in Fig. 5. Separate bridge-type rectifiers are employed for the field and armature circuits. A four-pole three-position switch is used to start, stop, and reverse the motor. Two poles reverse the armature voltage, one opens the input circuit to the adjustable transformer and one connects the dynamic braking resistor across the armature in the stop position. The switch is of the type which cannot be thrown directly from forward to reverse but must be held momentarily in the intermediate stop position. Opening the input to the Variac in addition to opening the armature circuit when stopping the motor interrupts the armature current with a minimum of arcing. Moreover this arrangement eliminates the autotransformer no-load loss during idle periods and reduces heating of the control box.

Since the field supply must operate in the stop position to provide dynamic braking, a separate transformer is used in the field circuit; this serves also to isolate the field supply from the armature supply to permit reversing of standard compound-wound motors having five leads. Also, since the circuit breaker must operate at the same value of armature current regardless of the speed setting, the breaker coil is placed in the transformer output circuit. It could also be placed directly in the armature circuit, but variation of the form factor with speed setting results in somewhat more variation of the operating point.

The field fuse is placed between the field transformer and rectifier. This prevents damage to the transformer in case of rectifier breakdown, but makes it desirable to use a fuse of the "slow-blow" type so that the initial surge of leakage current through the rectifier will not blow the fuse when the control is first turned on.

No essential changes are required when contactors are employed to provide push-button operation. A circuit utilizing standard a-c 4-pole reversing contactors (having five pairs of normally-open contacts) is shown in Fig. 6. One pair of contacts is placed in each armature lead, one in the input to the autotransformer, and two in the button circuits. The dynamic braking relay has a normally closed pair of contacts for the braking circuit and a normally open pair for the control circuit to prevent operation of either running contactor before the dynamic braking circuit has opened.

The choke is important both in improving the regulation of the armature supply and in reducing the a-c ripple current in the armature circuit. The minimum inductance that will insure continuous conduction through the rectifier, giving these advantages, is one having a reactance equal to one-third the equivalent load resistance, (load voltage divided by load current), at the line frequency. The required inductance is greatest, therefore, at maximum speed setting and minimum load. Insufficient inductance is indicated by a breaking away of the speed torque curve from the straight line at light loads and maximum speed. It is easiest to design the choke empirically so that the bend in the curve is just perceptible at the low-torque end. A small air gap in the core is employed so that the inductance will not drop off excessively at full load and increase the form factor.

In considering possible designs of controls, the essential factors limiting the output of the adjustable transformer must be kept in mind. So that the autotransformer brush may travel over the entire winding and give a variation of voltage from zero to maximum, the winding must be in a single layer. For a core of given size, therefore, the cross section of copper and consequently the power output is reduced as the number of turns is increased to give higher voltage operation. This fact is offset somewhat by higher brush losses at lower voltage, the net effect being that a 230-v Variac has 80 percent of the power rating of a 115-volt design using the same core.

Another factor limiting the output is the amount of overvoltage or boost that is provided. The usual design giving 0-135 v output for 115-v input makes the copper loss at the two points of maximum loss about equal. Any further step-up seriously reduces the output, so that when the 115-v input tap is used on a 0-270 v Variac, the output power rating is halved.

With controls using selenium rectifiers it is desirable to provide enough boost to give 115 or 230 v d-c output so that standard motors can be used at rated voltage. Variacs giving 0-150 volts a-c output for 115 volts input will deliver 115 volts on full load at the rectifier output and have been adopted for the $\frac{1}{3}$ and $\frac{3}{4}$ hp commercial controls which have been developed. This seems a good design, although the additional boost reduces the maximum output power about 10 percent. The best theoretical design would require the use of a motor wound for about 100 v. This seems undesirable in controls intended for general application. Where 230-volt operation is desired, a top rating of 300 v is provided. This gives an a-c power output about 70 percent of that of a standard autotransformer on the same core.

When the tube rectifiers are used,

Fig. 7—Coil winding machine with an adjustable voltage drive that permits a gradual start under full operator control, a wide range of winding speeds, and steady operation at any speed setting.

the proper amount of boost can be provided in the center-tapped step-up autotransformer required for the rectifier circuit. Variacs of standard design can, therefore, be employed.

Miniature selenium rectifiers usually are used for the field supply of commercial adjustable voltage controls. These rectifiers were developed for power supplies for radio and television sets and electronic equipment generally. For maximum life the output current should not exceed about 75 percent of the radio set rating. These stacks can be operated at full voltage, however, and provided that the back leakage when first installed is not excessive at the maximum expected line voltage, failures are not likely to occur.

A field supply fuse protects the field rectifier and transformer against wrong motor connections or a short circuit. When a tube rectifier is used, the time delay clock is connected beyond the field fuse to prevent the application of armature power unless the field fuse is in place and intact.

The overload breaker must open instantly in case of a short circuit and should also protect the motor and control against sustained overloads. At the same time, it should permit normal starting current several times the full-load value for several seconds. With tube rectifiers it is also necessary to protect the tube from starting currents of long duration in the event of a stall or the application of too heavy a load.

A magnetic circuit breaker of the time-delay type has been used in commercial Variac controls. For selenium rectifier models, the rectifier has sufficient thermal capacity to protect both the motor and rectifier. With a tube rectifier it has been found possible to match the time delay characteristics of the breaker to the short-period overload characteristics of the tube. In this way full advantage can be taken of the maximum tube rating on starting without risk of damaging the tube. When this is done, it is not usually possible with a single standard breaker to give protection also to the motor or control against sustained overloads, although starting protection is provided.

Applications

These controls supply constant torque over the working speed range. In applications such as lathe drives, two pulley ratios make it possible to handle either light work at high speeds or heavy work at low speeds with ample torque margin. A back-geared lathe requires only a single drive ratio.

In determining the number of drive ratios required, it should be remembered that it is frequently economical to provide a driving motor of greater capacity than with controls of other types. This is because the inherently low cost of the adjustable transformer controls and because no derating of the motor is required. A larger motor and control can frequently be provided at a lower cost than a smaller motor with a variable-speed transmission.

Applications requiring repeated fast starting have proved particularly suited to adjustable transformer controls. In the case of winding lathes for transformer coils, for example, winding must be stopped frequently for making taps and inserting paper so that maximum production depends on very fast acceleration, high-speed winding and fast and controlled breaking action. A design meeting these requirements employed a foot pedal operated adjustable transformer, a cam-operated switch to apply dynamic braking automatically at the low end of the speed range, and an auxiliary mechanical brake operated by a second pedal. The motor and drive pulleys were of low-inertia construction, so a speed of 5,000 rpm was reached in 3 seconds.

The compactness and simplicity of the controls makes possible their use in applications where adjustable-speed operation would not otherwise be feasible, as in the lathe-feed installation shown in Fig. 9. Indicated applications for the selenium rectifier versions of the control include also the cases where instant starting is required without standby power, or where the maintenance associated with controls of the electronic type cannot readily be provided.

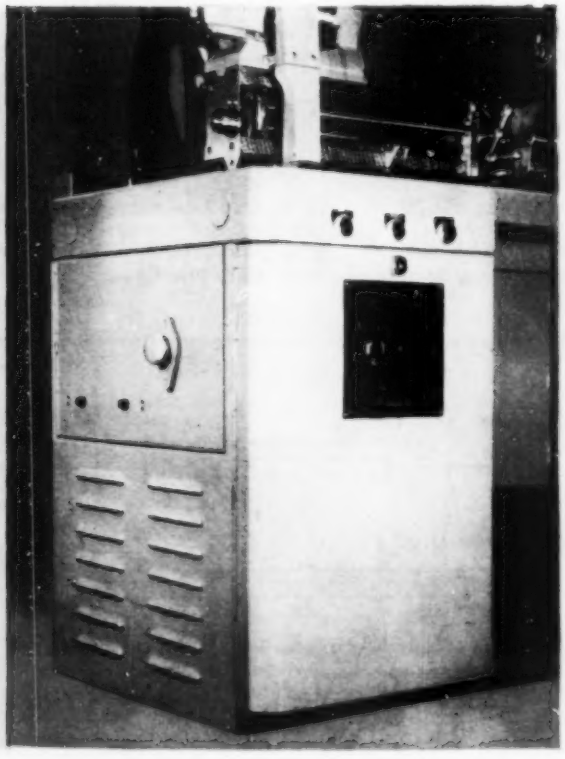
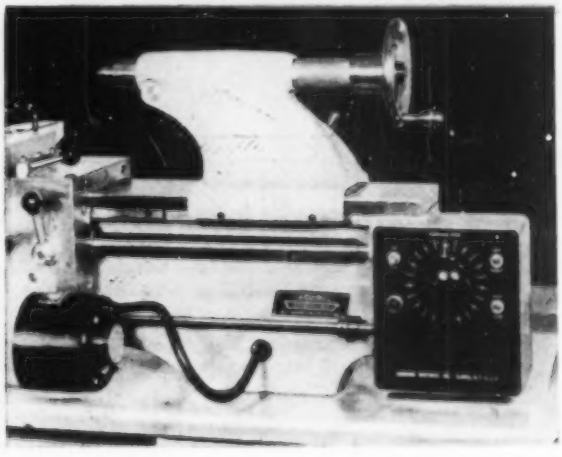


Fig. 8—Installation of a 1½ hp motor and control on a Rivett precision screw cutting lathe. Since back gears are available, this proved to be more power than required; one hp would have been ample. The installation is both simple and inexpensive.

Fig. 9—Adjustable voltage feed control for carriage and cross slide of a production lathe. The control, which is rated at 1/15 hp, utilizes selenium rectifiers. The feed is reversible and the feed rate can be varied.



Low Costs Methods of Coupling

Sixteen types of low cost couplings, including flexible and non-flexible types. Most are for small diameter, lightly loaded shafts, but a few of them can also be

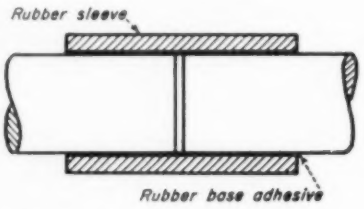


Fig 1—Rubber sleeve has inside diameter smaller than shaft diameters. Using rubber-base adhesive will increase the torque capacity.

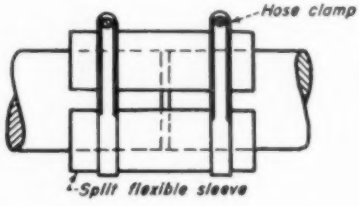


Fig 2—Slit sleeve of rubber or other flexible material is held by hose clamps. Easy to install and remove. Absorbs vibration and shock loads.

Fig 3—Ends of spring extend through holes in shafts to form coupling. Dia of spring determined by shaft dia, wire dia determined by loads.

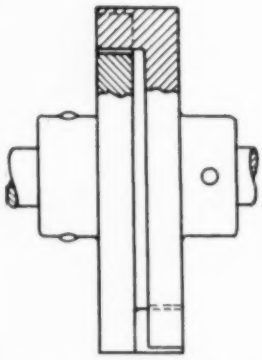


Fig 7—Jaw-type coupling is secured to shafts with straight pins. Commercially available; some have flexible insulators between jaws.

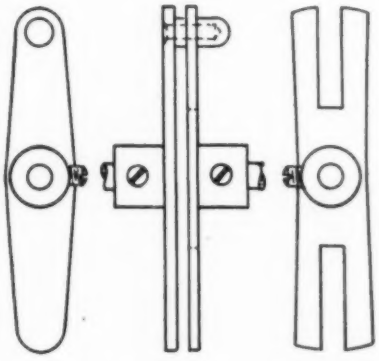


Fig 8—Removable type coupling with insulated coupling pin. A set screw in the collar of each stamped member is used to fasten it to the shaft.

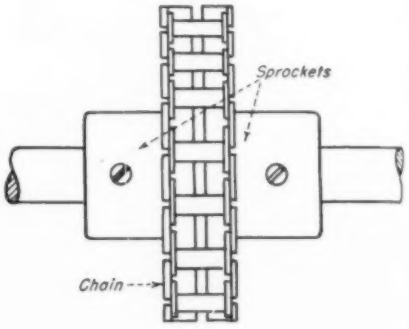


Fig 9—Sprockets mounted on each shaft are linked together with roller chain. Wide range of torque capacity. Commercially available.

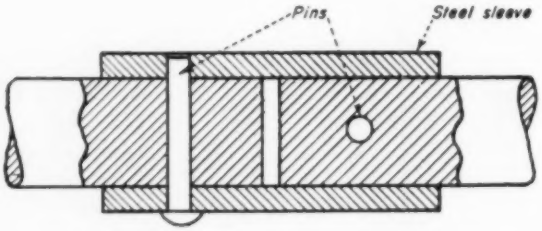


Fig 13—Steel sleeve coupling fastened to shafts with two straight pins. Pins are staggered at 90 degree intervals to reduce the stress concentration.

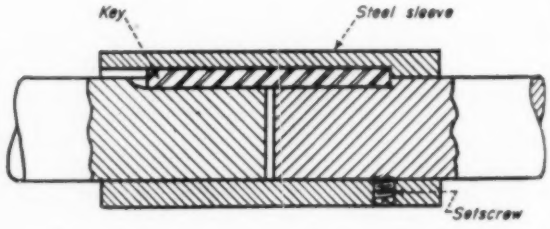


Fig 14—Single key engages both shafts and metal sleeve which is attached to one shaft with setscrew. Shoulder on sleeve can be omitted to reduce costs.

Small Diameter Shafts

adapted to heavy duty shafts. Some of them are currently available as standard commercial parts.

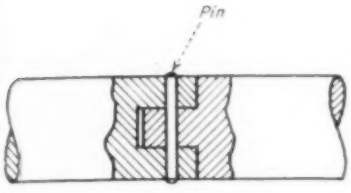


Fig 4—Tongue-and-groove coupling made from shaft ends is used to transmit torque. Pin or set screw keeps shafts in proper alignment.

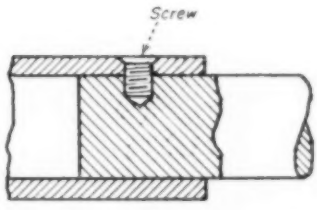


Fig 5—Screw fastens hollow shaft to inner shaft. Set screw can be used for small shafts and low torque by milling a flat on the inner shaft.

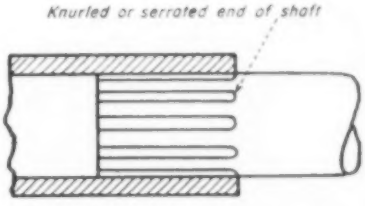


Fig 6—Knurled or serrated shaft is pressed into hollow shaft. Effects of misalignment must be checked to prevent overloading the bearings.

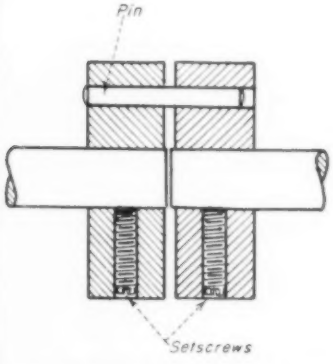


Fig 10—Coupling made of two collars fastened to shafts with set screws. Pin in one collar engages hole in other. Soft spacer can be used as cushion.

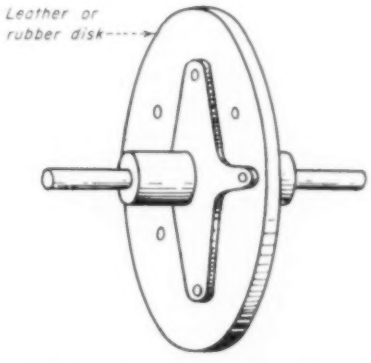


Fig 11—Coupling is made from two flanges rivited to leather or rubber center disk. Flanges are fastened to the shafts by means of setscrews.

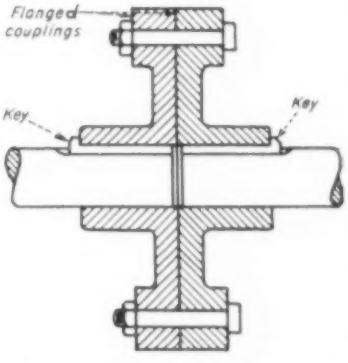


Fig 12—Bolted flange couplings are used on shafts from one to twelve inches in diameter. Flanges are joined by four bolts and are keyed to shafts.

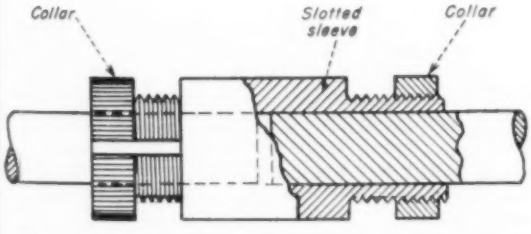


Fig 15—Screwing split collars on tapered threads of slotted sleeve tightens coupling. For light loads and small shafts, sleeve can be made of plastic material.

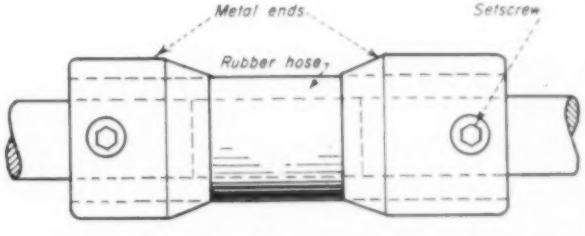
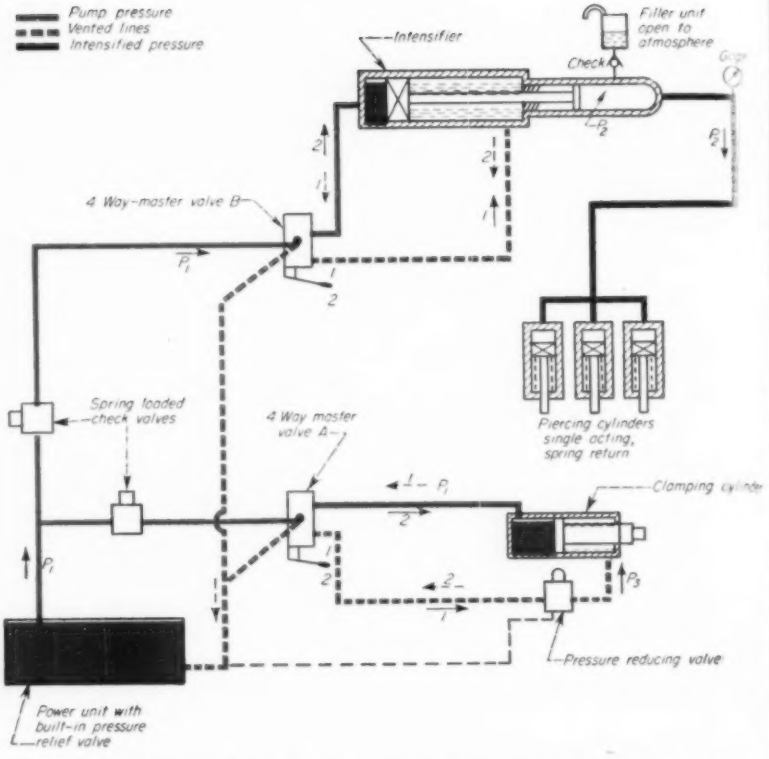


Fig 16—One-piece flexible coupling has rubber hose with metallic ends that are fastened to shafts with set screws. Commercially available in several sizes and lengths.

Multiple Pressure Hydraulic System

H. L. STEWART
Logansport Machine Company, Inc.



1. Intensifier circuit. Three different operating pressures are available in this hydraulic system. The clamping cylinders use pump pressure. The intensifier provides high pressure for piercing. A pressure reducing valve cuts pump pressure to a lower value for return of the clamp piston. Numbered arrows indicate direction of flow for each position of the valve handles.

MANY HYDRAULIC SYSTEMS contain a number of components requiring widely different pressures for their operation. For example, the clamping cylinders in a press generally operate at only a few hundred psi pressure while the main power cylinders may require several thousand psi pressure. To attempt to operate both at the same pressure would involve excessively large main cylinders and impractically small clamping cylinders. In addition, a large volume of oil would have to be supplied for the one unit and a small volume for the other. To avoid such a situation and to achieve a balance of system, it is essential that a high pressure be available for some units and a correspondingly low pressure for others.

The hydraulic units and methods that can be employed to obtain multiple working pressures include:

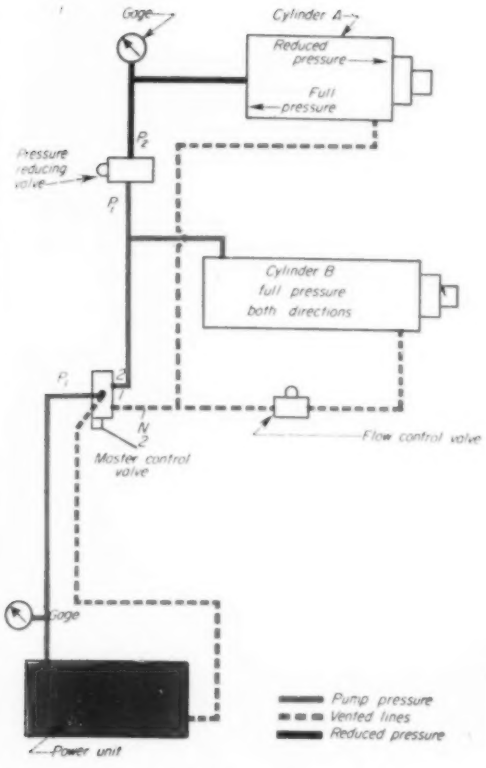
1. Pressure reducing valves
2. Pressure intensifiers
3. Separate high pressure and low pressure pumps
4. Relief valves
5. Unloader valves

Pressure reducing valves, as the name implies, reduces the pressure of the oil flowing through it. Basically, it is a spring loaded valve. A normally open, pressure reducing valve permits unrestricted flow of fluid until pre-determined pressure is reached. The valve then operates automatically to restrict flow and maintain constant delivery at outlet port. Excess fluid bleeds through drain port to reservoir. If line pressure falls, valve opens wide to hold delivery pressure constant. A wide range of pressures is easily obtained by adjusting the valve.

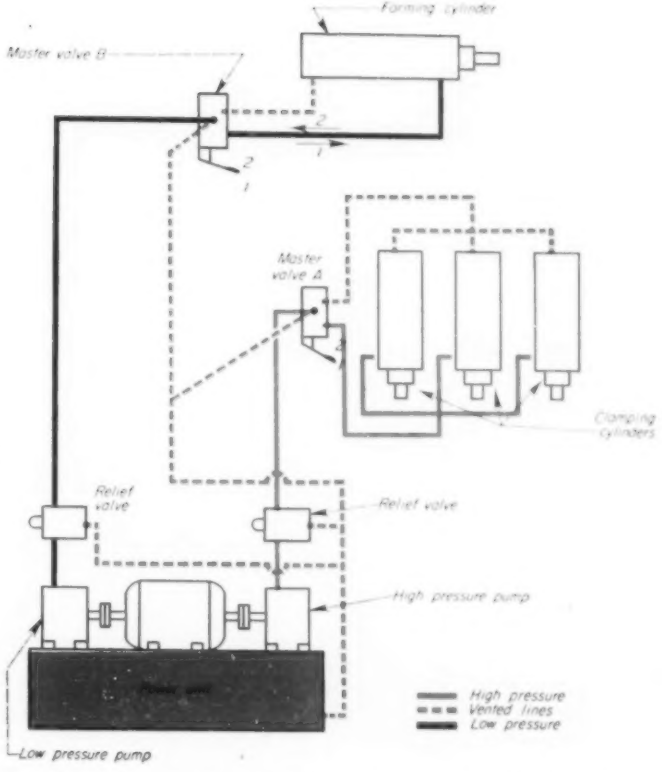
The reverse of pressure reduction is pressure intensification. Low pressure oil is furnished to a large cylinder that is mounted integrally in tandem with a smaller diameter cylinder. The pressure developed will be inversely proportioned to the piston areas. Such a unit does not cause any temperature changes, neglecting friction and leakage, because the energy input and output of the unit are substantially equal. There is no theoretical limit to the maximum pressure difference that can be developed but the volume of high pressure oil delivered will be inversely proportional to the ratio of pressure output to pressure input. The volume of high pressure oil per stroke is relatively small for high pressure ratios.

Rotary pressure intensifiers have been developed. Their basic characteristics are the same as those of cylinder intensifiers except that they are intended to give "continuous" flow. On the other hand, a single double acting cylinder unit delivers no high pressure oil at the end of the stroke and a single acting unit delivers no oil on the return stroke. The rotary unit is in effect a combination of cylinders and so cannot deliver an absolutely steady flow of high pressure oil. There are bound to be pulsations.

For operating power cylinders, the single cylinder intensifiers meet all the requirements if the displacement of its high pressure end is slightly greater than the total volume required on the power stroke of the working cylinders. It is a simple unit and is used extensively.



2. Pressure reducing valve circuit. Pump pressure is available for the operation of cylinder B while a reduced pressure is fed to cylinder A on the out-stroke portion of the cycle. The pistons of both cylinders are retracted under full pressure.



3. Two pump circuit. Actually there are two independent hydraulic systems in this machine, having a common vent circuit. Pressure of each pump is set independently by means of a pressure relief valve. Separate pumps require separate supply lines to the working elements, so that the lines should be kept short for economy.

DUAL-PUMP SUPPLY. Separate high pressure and low pressure pumps are generally used when large volumes of both high and low pressure oil are required. The pumps may be separate units or designed into one common body in order to conserve space. Which of these types is used is immaterial insofar as hydraulic operating features and characteristics are concerned.

Relief valves are substantially pressure reducing valves in that they limit the operating pressure that can be applied to the unit. If the pressure goes higher, the valve opens and by-passes the oil back to the tank or reservoir. Relief valves cause heating of the oil. Whenever oil flows through a valve or orifice from a region of high pressure to one of low pressure, there is a loss of hydraulic energy, the loss being converted to heat. The amount of energy converted to heat is proportioned to the pressure drop times the volume of oil. The temperature rise of the oil, neglecting the heat losses to the surroundings, will be proportional to the pressure drop.

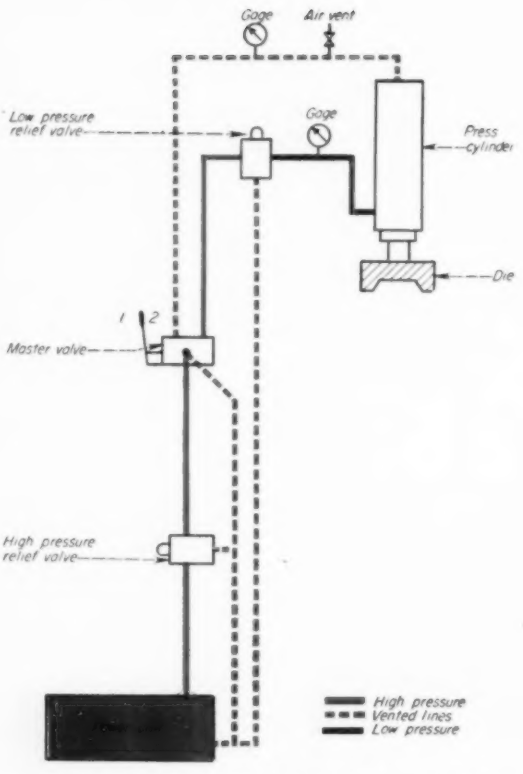
A frequent error in hydraulic thinking is to confuse pressure control and volume control. For example, a throttling orifice is volume control rather than pressure control. If the flow on the low pressure side of the orifice ceases, the pressure almost immediately builds up to the pressure on the high pressure side of the orifice. On the other hand, pressure reducing valves do not depend on rate of flow to achieve the pressure reduction. Once set to hold a given pressure, they maintain the same pressure at full flow or zero flow.

INTENSIFIER CIRCUIT. The hydraulic circuit in Fig. 1 makes use of an intensifier, a pressure reducing valve and a pressure relief valve to provide three different operating pressures from a single power unit. Hydraulic power flows from the power unit to the spring loaded check valves. These valves are installed to prevent pressure drop-off in the system as the various cylinders are actuated.

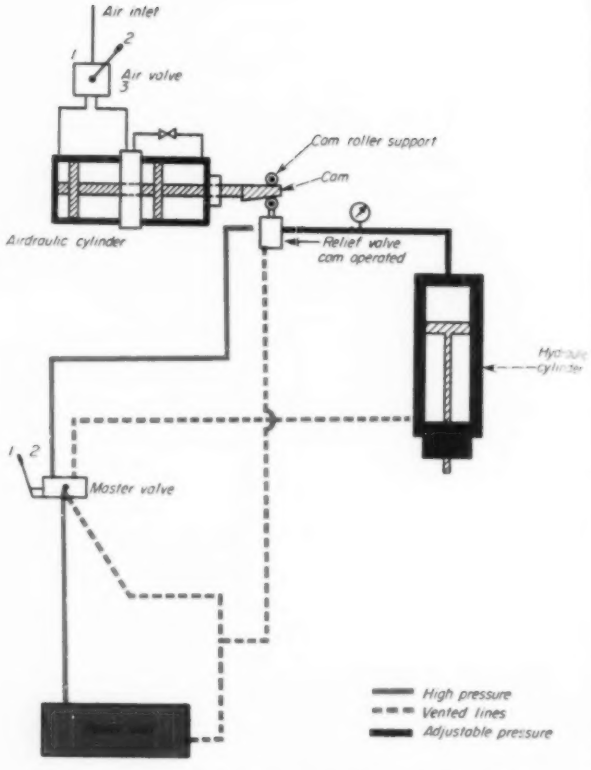
When the handle of the four-way valve A is shifted to position No. 2, pump pressure is admitted to the blind end of the clamping cylinder. The piston rod of this cylinder moves out against the work piece. At the end of the stroke of the clamping piston, the operator puts four way valve B to position No. 2 so oil at pump pressure flows to the blind end of the intensifier cylinder. High pressure oil from the output end of the intensifier powers the operation of the piercing cylinders.

After piercing is completed, valve A is returned to position No. 1 directing pump pressure to the front end of the intensifier. This relieves the oil pressure in the piercing cylinders so that the spring-loaded pistons in these cylinders retract. The intensifier is equipped with a filler tank and check valve. The filler tank makes up any oil lost by leakage in the high pressure circuit.

As the last step, the operator shifts the handle of valve A to position No. 1, allowing oil to flow through the reducing valve. This prevents the piston from slamming on the return stroke. While a flow reducing valve could also prevent slamming, it is undesireable to put such restrictions in a power line. (*continued on next page*)



4. Relief valve circuit. Since the press ram remains in the elevated position for long intervals of time, low pressure relief valve is incorporated in the "retract" circuit. Thus, pump does not have to labor against high pressure during the dwell periods.



5. Cam-operated relief valve circuit. Pressure in the upper hydraulic line is determined by setting of the relief valve. The stem of the valve carries a roller which is in contact with a pneumatically actuated cam. When the cam is at its outermost position, line pressure is a maximum.

REDUCING VALVE CIRCUIT. The system in Fig. 2 illustrates the use of a pressure reducing valve to provide two operating pressures from one pumping unit. High pressure is required for the out-stroke of one hydraulic cylinder and low pressure for the outstroke of the second. The power unit is furnished with an adjustable relief valve.

In this installation, a four-way master control valve is in the outlet line from the power unit. The master valve is of the open center type so that in the neutral position oil from the power unit is dumped back to sump at atmospheric pressure.

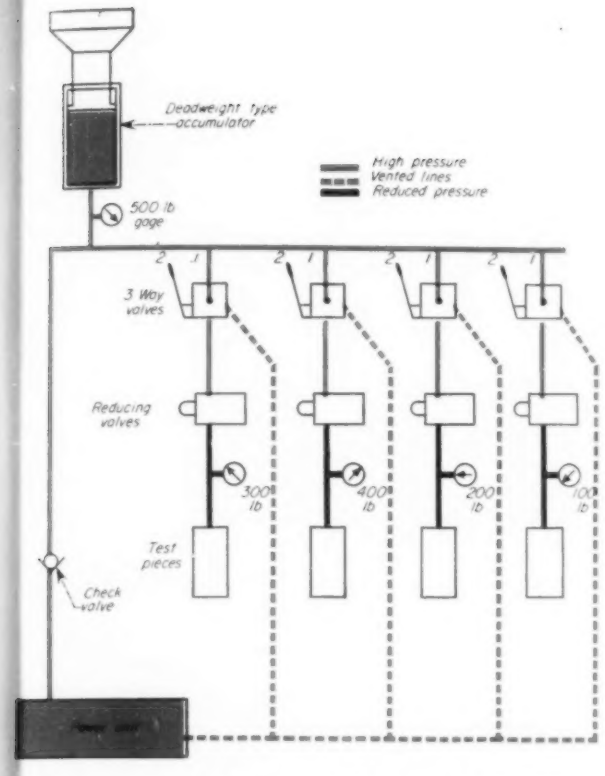
When the operator shifts the master valve handle to position No. 2, oil flows directly to the blind end of cylinder B and through the pressure reducing valve to the blind end of cylinder A. Cylinder B operates under full pump pressure as determined by the relief valve. The speed of the piston of this cylinder is regulated by the flow control valve. The piston of cylinder A extends under the hydraulic pressure established by the setting up of the pressure reducing valve. For return of both pistons, the master valve is shifted to position No. 1. Full pump pressure is admitted to the piston ends of the cylinders for rapid return operation.

TWO PUMP CIRCUIT. The two different operating pressures required in the hydraulic circuit, Fig. 3, are supplied by separate pumps. A double end electric motor drives the high pressure and low pressure hydraulic pumps. The pressure output of each pump is adjusted by means of a relief valve.

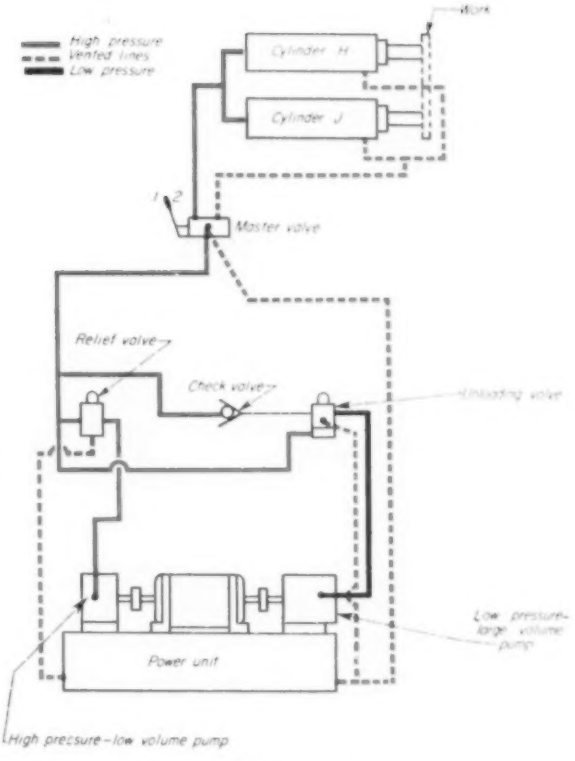
Action of the forming cylinder is controlled by a four-way master valve. When the operator puts the handle of valve A in the No. 2 position, oil from the high pressure pump is admitted to the blind ends of the clamping cylinders. When the work has been secured, valve B is shifted to position No. 2 so that low pressure oil powers the forming operation. All pistons are returned when the master valves are shifted to the No. 1 positions.

RELIEF VALVE CIRCUIT. This system, Fig. 4, makes use of two pressure relief valves to give two distinct working pressures in the same circuit. This circuit performs satisfactorily in a hydraulic press application where high pressure is needed for the down stroke of the ram, while a lower pressure will suffice for the upstroke. Often in such presses, the standby period, during which the ram is in the elevated position, is much longer than the actual pressing interval. If high pressure were used to elevate the die, the pump would be laboring against this pressure for considerable lengths of time. The oil would tend to overheat, causing packing failures, excessive leakage and breakdown of the oil. Thus, a low pressure relief valve in the elevating circuit is an advantageous choice just from the standpoint of maintenance.

As an alternative a three position, open center master valve might be selected to vent the pump during standby. But if the die is heavy, the weight may cause the ram to



6. Accumulator and pressure relief valve circuit. The accumulator acts as a storage tank for oil under pressure, permitting intermittent pump operation. Pressure to test pieces or cylinders are determined by setting of the pressure relief valves. Limit switch on accumulator ram controls pump motor.



7. Two pressures, two flow rates in one system. At start of cycle, oil from both pumps moves the pistons out to the work. Then, as the pressure builds up, the low pressure pump is vented automatically and the pressure from the high pressure pump builds up to the full relief valve setting.

drift downward. In addition, the third valve position would complicate the control of the machine for the operator. In the circuit shown, a two position, four-way master valve is employed. The low pressure relief valve is set so there is just enough pressure to keep the ram and die in the raised position during the dwell period. Since the pressure drop through the relief valve is thereby kept at a minimum, heating of the oil is proportionately low.

Referring to Fig. 4, when the master valve is shifted to position No. 1, oil flows from the power unit through the high pressure relief valve to the blind end of the pressing cylinder. Ram and die are forced against the work. For elevation of the ram, the master valve is placed in the No. 2 position, allowing oil to flow to the piston end of the cylinder through the low pressure relief valve.

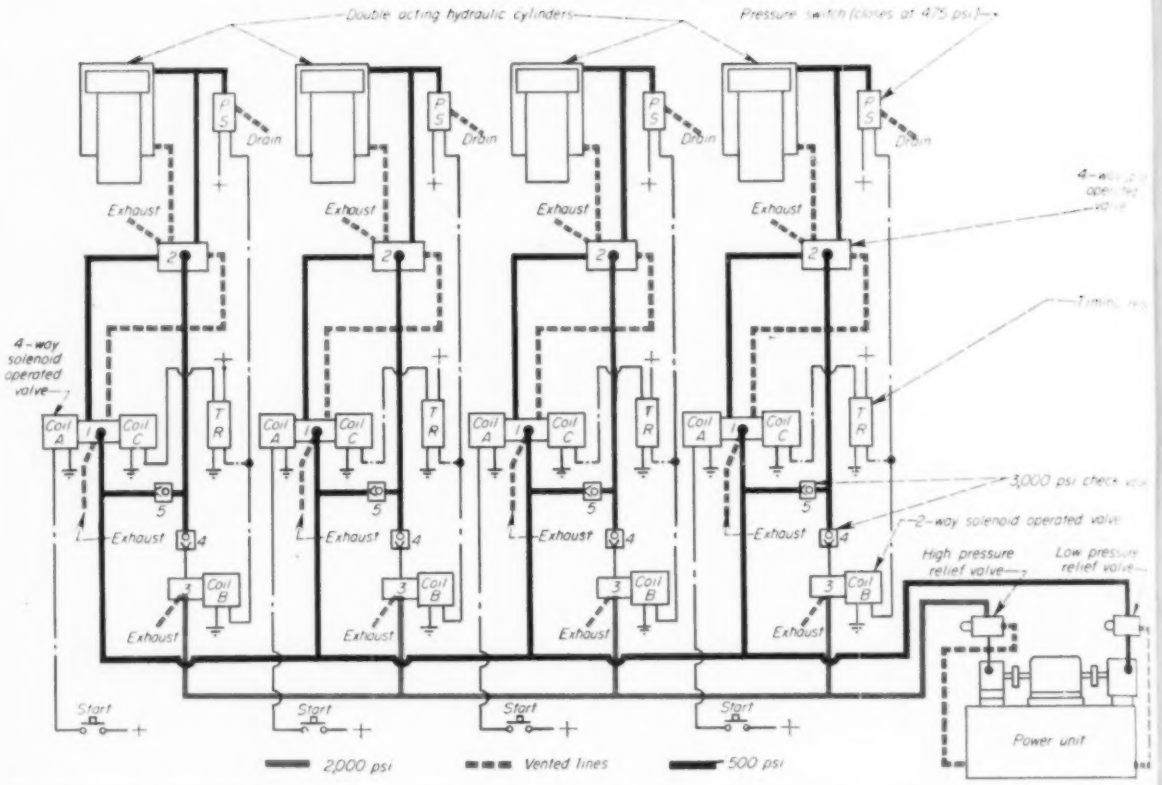
CAM OPERATED RELIEF VALVE. The system of Fig. 5 uses a cam-operated relief valve to provide continuously adjustable pressure in one line. The setting of the relief valve is changed by means of an airdraulic cylinder, which is an air powered cylinder with a closed circuit hydraulic dashpot for accurate positioning. The piston rod of the airdraulic cylinder carries a cam, which engages a roller on the relief valve stem. When this cam is at its outermost position, pressure in the line is at a maximum.

While in this application the relief valve is pneumatically set, other means of actuation are often used. For example, the valve can be adjusted mechanically by a cam on the press ram or by a motor driven rotating cam that establishes a program of pressure. Thus, it can be seen that the cam operated relief valve offers many possibilities for remote operation and flexible circuits. Hydraulic lines to remote cylinders can be kept short.

For operations, the master valve is moved to position 1, causing oil to flow from the power unit, through the relief valve to the blind end of the hydraulic cylinder. The low pressure oil starts the ram on its outstroke. When the ram encounters the work, the operator shifts the handle of the four-way, three position air valve. The piston rod of the airdraulic cylinder moves out and the cam on this rod forces the relief valve stem down. This causes the pressure to build up on the blind end of the hydraulic cylinder.

The cam can be stopped in any desired position by moving the handle of the air valve to the third position. After the operation is completed, the handles of both the air valve and the master valve are shifted again. The hydraulic ram and the cam retract to their original positions.

ACCUMULATOR CIRCUIT. This circuit utilizes a dead weight accumulator and four pressure reducing valves to give several pressures in a single system. The accumulator acts as storage tank for oil under pressure. When the ram of the accumulator drops to a certain point, an electrical contact is made, turning on the power unit. The accumulator is pumped up until the weight is at the top of its stroke. At this point another electrical contact is



8. Electrically controlled system. High and low pressures are supplied to system by separate pumps. The pressure switches and timing relays control the changes-over from low to high pressure during each operating cycle. A pressure of 500 psi is required to advance the piston, while the pressure needed for the molding operation is 2,000 psi approximately. In large multiple circuit systems like this one, two smaller units are often more easily installed and serviced than a single large pump

made and power unit is shut off. On this type of circuit, the power unit operates intermittently.

In the system depicted in Fig. 6, four cylinders are to be tested at four different pressures. The operator starts the power unit, filling the accumulator. The check valve prevents the accumulator from draining through the pump when the power unit is idle. A control valve is installed in each of the hydraulic lines leading to the four cylinders. These valves are of the three-way type, with inlets blocked in the No. 1 position.

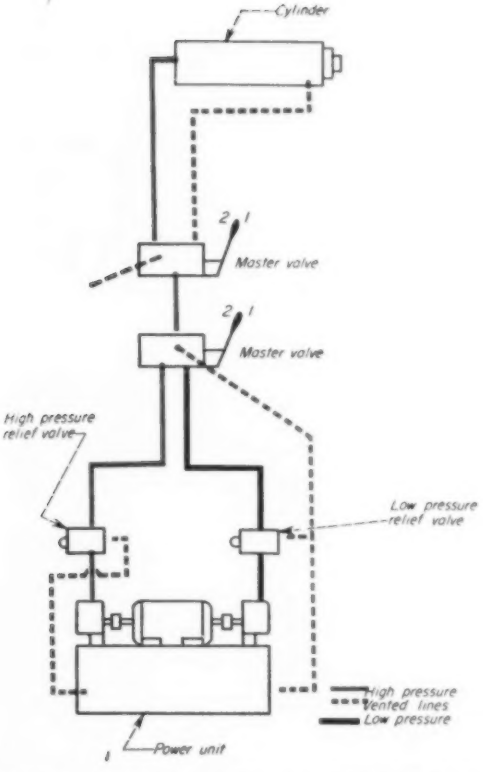
The test pressures desired are set by the four reducing valves. The cylinders are put under pressure when the operator shifts the three way valves to their No. 2 positions. The pressures on the cylinders can be checked on individual gages. At the end of the test, the handles of the control valves are returned to the No. 1 positions, blocking the inlets and relieving pressure on the cylinders.

TWO PRESSURES, TWO FLOW RATES. This circuit makes use of a high pressure—low volume pump, a low pressure—high volume pump, a relief valve and an unloading valve to provide an automatic change of hydraulic pressure in a system. Such a circuit is used to advantage on presses where a large volume of oil at low pressure is needed to move the ram against the work. After positioning of the ram, the pressing operation calls for a higher pressure, but at a considerably reduced rate of flow. With the arrangement shown in Fig. 7, fast approach speeds can be obtained from a power unit having a drive motor of comparatively low rating. Heating of oil is also less than would occur with a single high pressure pump.

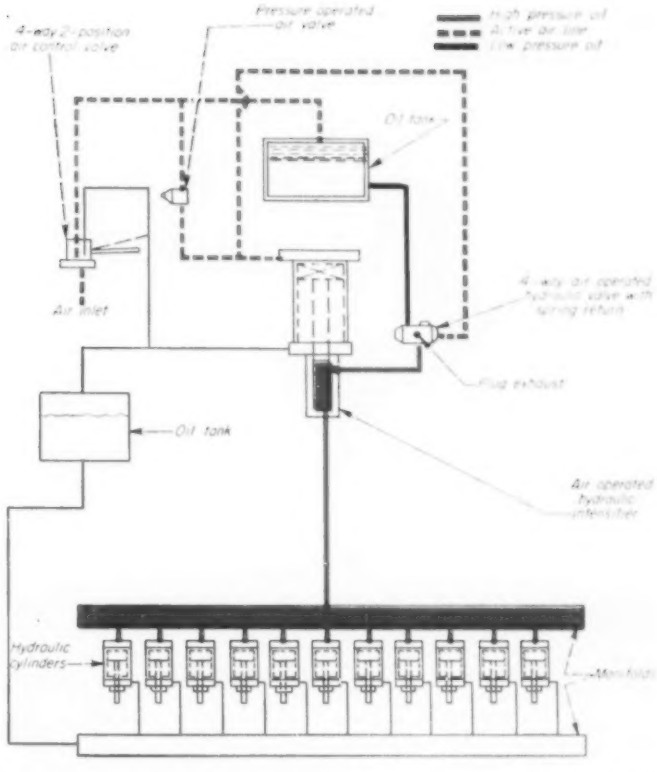
When the operator shifts the handle of the master control valve to the No. 2 position, oil flows from the low pressure pump through the unloading and check valves to the cylinders. At the same time, the high pressure pump also supplies oil to the cylinders. When the pistons encounter the work, pressure in the high pressure low volume pump begins to build up to the relief valve setting. The check valve prevents the high pressure oil from flowing to the low pressure pump.

The unloading valve is a hydraulically operated, three way valve. When the line pressure rises to a certain point, this valve is shifted automatically, venting the low pressure pump. In effect, the low pressure pump is a booster unit that supplies large volumes of oil to take up the space created by moving piston. The more expensive high pressure pump need not supply oil for the entire operation.

TWO PUMPS, ELECTRICAL CONTROL. In Fig. 8 is shown a schematic drawing of the arrangement of a bank of hydraulic cylinders in a molding machine. A pressure of 500 psi is used to advance the pistons, while the pressure required for the molding operation is 2,000 psi, approximately. These pressures are supplied by separate pumps, driven by a common electric motor. The admission of the two pressures to the cylinders is controlled



9. Two pumps, manual control. Individual pumps supply the high and low pressures required to operate the piston of a press. Two four-way valves in series control the movement of the piston and the pressure on the cylinder.



10. Air-operated hydraulic intensifier. At the stage in the cycle shown above, the build up of air pressure has opened the pressure operated air valve and shifted the air operated hydraulic valve. The intensifier begins to raise the pressure on the forming cylinders. One use for such a system is in a plant equipped with a central air system.

electrically. Operation of each of the four systems is identical.

When a start button is depressed momentarily, coil A of the corresponding four way, solenoid operated valve is energized. Action of this valve causes the four way pilot operated valve to be shifted hydraulically, admitting low pressure oil to the blind end of the cylinder. When the piston is fully advanced, the pressure builds up sufficiently for the pressure switch to close. This energizes the timing relay and coil B of the two way, solenoid operated valve. Action of this valve admits oil at 2,000 psi to the cylinder for the molding process.

After pre-set time period has elapsed, the timing relay contacts close the circuit to coil B of valve No. 1. The valve reverses, as does valve No. 2 and oil is admitted to the piston end of the cylinder. The instantaneous pressure drop in the line allows the pressure switch to open. Then, the two-way valve cuts off the high pressure and the pistons retract under 500 psi oil. With electrical control, flexibilty of operation is high.

TWO PUMPS, MANUAL CONTROL. This system, Fig. 9, employs a power unit with two pumps, one for high pressure and one for low pressure. Control is by means of two four way, hand operated master valves.

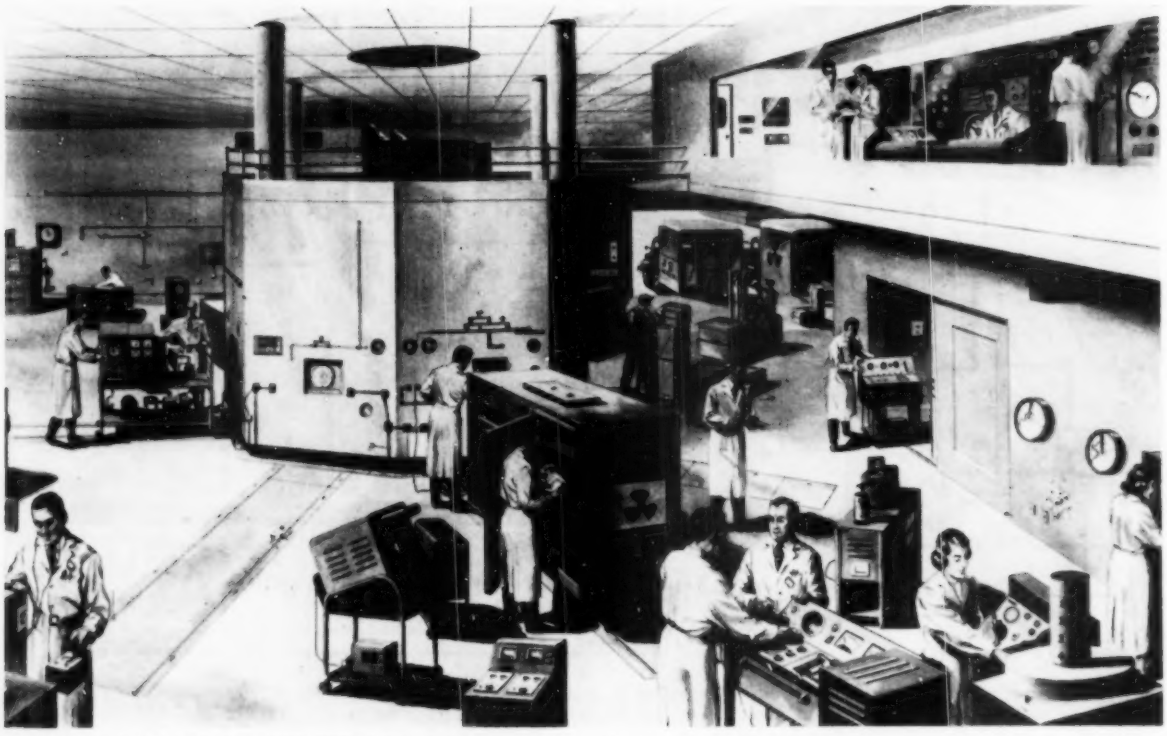
With the handles of the lower valve in position No. 1, the upper valve is shifted to position No. 2, directing low pressure oil to the closed end of the cylinder. The piston moves out to contact the work. Then, the operator moves the handle of the lower valve to position No. 2, venting the lower pressure pump and allowing high pressure oil to act on the piston. The piston is retracted under low pressure when both valves are returned to their No. 1 position. Fundamentally, cost is proportional to pressure so oil should be supplied at low pressure where possible.

AIR-OPERATED HYDRAULIC INTENSIFIER. The circuit in Fig. 10 makes use of air to supply oil at two different pressures to a bank of hydraulic cylinders. Air is the control medium, also.

At the start of the operation, the four-way air valve is shifted, allowing air to flow to the upper oil tank. Air pressure forces oil through the air operated hydraulic valve, through the lower end of the intensifier and on to the bank of forming cylinders. When the pistons of these cylinders encounter resistance, air pressure builds up in the line, causing the pressure operated air valve to open. Then, air flows to the upper end of the intensifier and to the pilot connection of the air operated hydraulic valve. Action of the latter blocks the line between itself and the intensifier. At the same time, air pressure forces the intensifier piston downward, increasing the pressure acting on the bank of cylinders.

After the operation is completed, the handle of the air control valve is shifted again, admitting air to the rod end of the intensifier and to the lower oil tank. The intensifier piston returns to its original position and the forming pistons are withdrawn also.

TECHNICAL NEWS



PEACEFUL USES OF ATOMIC ENERGY will be extended by experiments in this nuclear laboratory. Artist's conception pictures the laboratory in operation. A single uranium fuel charge will operate the unit for 10 years without refueling.

Low Cost Nuclear Reactor Designed To Study Non-Military Atom Uses

A LOW POWER, LOW COST NUCLEAR REACTOR has been designed by North American Aviation for the Atomic Energy Commission. The reactor is a research tool which will be used to extend the non-military uses of the atom. A single uranium fuel charge will operate it at a power level of 160 kilowatts eight hours a day, five days a week, for 10 years, thus eliminating the need for frequent disposal of radioactive residue.

Design of the reactor is such that it is impossible for it to "run away"; that is for its power to rise dangerously fast so that it would destroy itself. Automatic devices trip safety rods and shut down the reactor should the power begin to rise rapidly. In addition, it has a negative temperature coefficient of reactivity. As the temperature inside the reactor rises, neutron production decreases.

There are, in general, two types of experiments possible with the reactor: the "in pile" type which uses the neutron flow inside the reactor, and the type in which a neutron beam is led through a port in the shield and used to irradiate objects outside the reactor.

In addition to experimental work and production of "tagged atoms" for industrial and university research, the reactor can be used for experiments on reactor development, and for training of scientific and engineering personnel in operation and use of a reactor.

Physically the reactor is octagonal in shape. It stands 11 feet high, is 19 feet wide and weighs approximately 450 tons. Its core consists of graphite and enriched uranium sealed in an aluminum tank. This is surrounded by reflector graphite. On top and bottom of the reflector and on the side of six of the eight surfaces of the octagon are several feet of concrete to shield operating personnel from radiation. The reflector graphite is continued, beyond a bismuth shield which stops gamma rays but not neutrons, to the other two reactor faces. A removable cadmium and lead shield at these latter faces provide access to thermal, or "slow" neutrons diffusing through the graphite. This arrangement is called a "thermal column". The shield at the top of the core is also removable, so that the core may be removed and replaced with the aid of an overhead crane.

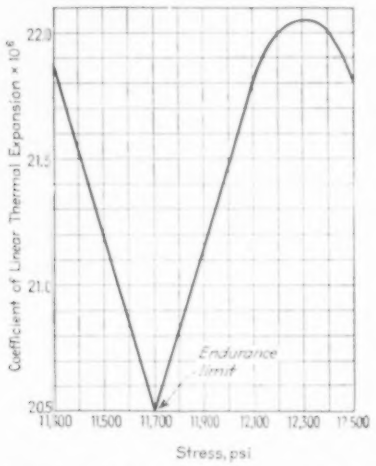
The reactor operator sits at a console desk in the control room overlooking the main floor. From this point he may observe the experiments in progress. He can hold the reactor power within design limits by changing the setting of the neutron absorbing control rods of cadmium which can be moved in and out of the core.

Because the power produced by a chain reaction in an atomic furnace appears as heat in the fuel and its surroundings, it is necessary that the reactor be cooled. This is accomplished by passing heavy water through a closed cooling circuit, along which the heat is removed.

Dilastrain Method Speeds Research By Cutting Endurance Limit Test Time

A RAPID AND ACCURATE METHOD for determining the endurance limit of metals and plastics, used for moving mechanical parts such as turbine blades, aircraft propellors, drive shafts and the like, has been devised at Rensselaer Polytechnic Institute. This new development, called the R/S Dilastrain Method, will speed the search for new alloys and materials by sharply reducing testing time.

The Dilastrain Method is based on the fact that identical samples from a rod of steel or other material, when heated under exact controls to the same temperature, possess rates of linear expansion which vary with the amount of stress to which each test



SHARP DIP in this curve accurately locates the endurance limit.

piece has been previously subjected. The apparatus measures such linear expansion to an extremely sensitive degree. By plotting these measurements against the varying stresses of the test bars they can accurately determine just where the endurance limit occurs in the particular material.

Only two hours is required for the test itself, and if time for preparing the material for testing is included, a complete test may be finished within ten hours. This compares with months, and sometimes as much as a year, required under present methods for accurately determining the endurance limit of an alloy.

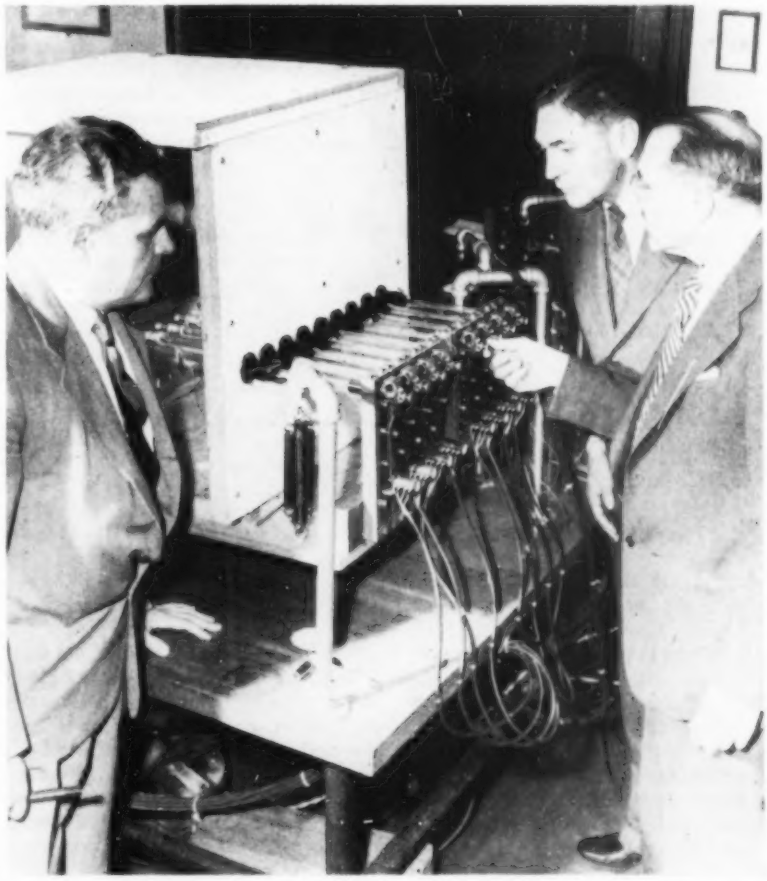
As it is presently being demonstrated in the Rensselaer Laboratory, the device uses small test pieces which are fashioned from customary test bars, six inches long and three-eighths of an inch thick. The central two inches are machined down to a diameter of about two-tenths of an inch and then the bars, eight in number, are stressed in a definite range.

This range is determined by first finding the yield point or elastic limit of the material. If the yield point of a metal, for example, is 50,000 pounds per square inch, the eight test bars are stressed from 60,000 pounds per square inch down to 25,000 pounds per square inch, at 5,000 pound intervals. All eight are then subjected to 100,000 cycles of vibration to put them on an even level of fatigue. An underwater jig is then used to slice off the ends of each bar and leave the central section in the shape of a small spool, with a two-inch long shaft and a small head on each end.

The prepared specimens are placed in a bank of eight Dilastrain multipliers. Each has a quartz tube 20 inches long which contains a quartz rod. One end of the rod rests against the end of the test specimen and the other extends against a steel lever. During this operation the room temperature is at 68 degrees F or 20 degrees centigrade and each of the multipliers is immersed in an air bath at this temperature. As the temperature of the air bath is gradually raised to 212 degrees Fahrenheit or 100 degrees centigrade the expansion of the test specimen is transmitted by the quartz rod to the steel lever. The movement of the lever is automatically recorded with a total magnification of 3,500 times the expansion of the specimen.

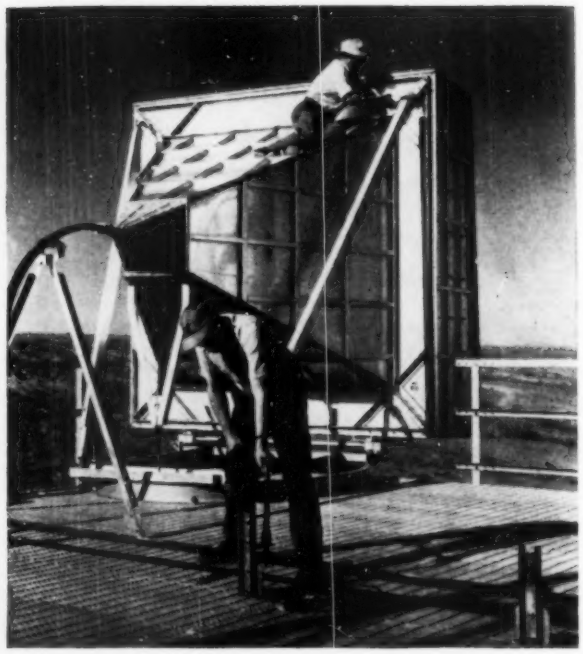
In approximately two hours the total linear expansion of each of the eight test specimens has been recorded. When these values are plotted against the stresses previously applied to the specimens, it is found that a sharp dip in the resulting curve appears at the point where the test material reaches its endurance limit.

The accuracy of the R/S Dilastrain Method has so far been determined in tests on samples of duraluminum, magnesium, soft, medium and hard steels, naval brass and polystyrene.



DILASTRAIN MULTIPLIERS measure rates of linear expansion of samples which have been previously stressed as temperature is increased to 212 deg. F.

107 TOWERS and stations like this speed television broadcasts across the country. 3000 mile journey requires 1/50 second.



HORN SHAPED ANTENNA contains a unique lens for focusing microwaves, just as an optical lens focuses light waves.

Tower Network Speeds TV From Coast to Coast

HEART OF THE NEW COAST-TO-COAST TELEVISION SYSTEM built by the Bell Telephone System is the longest chain of radio-relay stations in the world. A string of 107 towers are spread over the 3,000 mile route at intervals of about 28 miles.

Television programs are converted into micro-waves which are shot through space to the next tower along the route by a highly directional horn-shaped antenna. This antenna contains a unique lens which concentrates the radio energy into a narrow beam. Composed of strips of metal imbedded in a special pattern in blocks of plastic foam—these lens are placed in front of the one-ton antenna. Because of the efficiency of the lens, less than one watt of electricity is required to bridge the gap between towers. At the neighboring station, the microwave beam is captured by another lens-type antenna, amplified and relayed onward.

The network is capable of transmitting six channels at one time. These channels are separated at each station by a filtering system. The microwaves are carried from the antenna by hollow rectangular pipes called wave guides. Inside the guides are assemblies of metal rods and disks which do the actual filtering. As the six incoming channels pass through the wave guide, the first filter directs one channel into an amplifier and allows the remaining five channels to pass. The second filter directs a second channel and so on until each channel has been routed to an amplifier. The system will also carry telephone calls.

Permanent Scientific Teams for Foreign Countries

A PROGRAM to bring scientific and technological matters to bear on foreign policy has been set up in the State Department. High-ranking scientists have been assigned in the Washington Office of the Department and at key foreign posts to carry out this program.

An important characteristic of this program consists of reporting on scientific and technological developments abroad, such reporting to arise from our scientists meeting foreign scientists, engineers and research men and exchanging unclassified information.

The proposal for such a program was outlined in a report, "Science and Foreign Relations", prepared last year by Dr. Lloyd V. Berkner, former scientist on the staff of the Carnegie Institution of Washington and now President of the Associated Universities, Inc.

The Berkner report pointed out that "the Department must be responsive to the general requirements of private as well as government agencies" in the matter of the collection abroad of scientific and technological information. It went on to observe that there is already an enormous international flow of such information but that "there are serious gaps and irregularities in this flow, and it is to the removal of these deficiencies that the efforts of the Department should be directed."

The report stated that there is a three to five year lag in the flow of information to this country from some science areas. This is mainly because publication of research results takes time. This gap, will be closed by current reports on scientific and technological developments in foreign countries.

As to dissemination of scientific and technical information in this country, the Berkner report felt that the mechanisms were not satisfactory. The report observed that the State Department does not bear responsibilities for dissemination of scientific information beyond the Government, but it went on to suggest that "it is in the United

States interest that such information be placed in the hands of the user by the most expeditious and effective means." Toward this end, the report continued, the Department "should collaborate closely with the efforts of the National Research Council and the national libraries in the development for public dissemination of foreign scientific information.

The Department has begun to staff its overseas science offices. Scientists on overseas science staffs rank as attaches with diplomatic status, and are appointed as officers in the Foreign Service Reserve for periods ranging from fifteen months to three years.

Glass Paper Solves Filter and Electrical Problems

PAPER COMPOSED entirely of glass fibers, with no additive, has been made for the first time at the National Bureau of Standards in cooperation with the Naval Research Laboratory. The raw material, commercially available fine glass fibers, was mixed with water and formed into continuous sheets on the semi-commercial papermaking machine in the NBS experimental paper mill. Glass paper was considered an impossibility until now.

The all-glass paper has several important applications. As an air-filter paper, it is many times more effective than present commercial filters. It seems particularly valuable for gas masks and respirators used by firefighters, industrial and medical workers, and military personnel. In gas-mask tests in a smoke-filled room, only one smoke particle in 100,000 passed through the glass-paper filter.

Until now, many air filters have relied considerably on imported raw materials. Glass, however, can be produced from raw materials found abundantly in the United States.

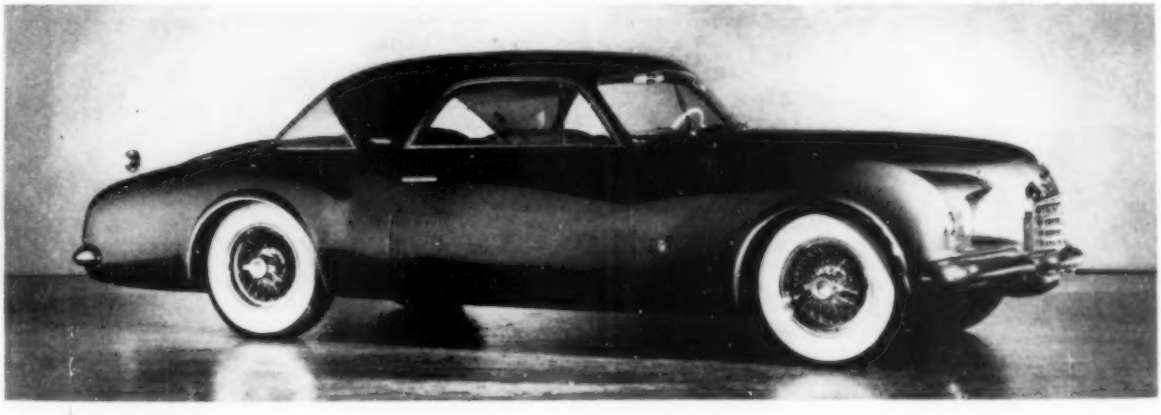
Another important advantage of the all-glass paper is its high resistance to effects of heat, moisture, chemicals and micro-organisms. It has excellent electrical characteristics and should be valuable as an insulator and dielectric. It can be used to make oil-impregnated paper capacitors capable of operation even at temperatures above 200 C.

First Plastic Molded Motor

A MOTOR, utilizing a plastic as its sole structural material has been molded by Rexford Plastics for the El Ray Motor Company. Metal is used only in the electrical and magnetic circuits, in the shaft and for all assembly screws. The 1/100 hp, 19,000 rpm, 28 volt d-c motor was designed primarily to power small blowers to cool electronic or other instruments.

NON-METAL MOTOR reduces weight and size with plastic structural parts.

The new motor is designed around a frame and housing of Plaskon Alkyd in which an Alnico ring magnet is embedded during molding. One end cap is molded integrally with the main housing, while the other, separately molded, carries the brushes, one bearing and holes for assembly. Each part has a depressed well into which the shaft bearings are press fitted. The molded plastic, therefore, simultaneously houses the motor, supports the shaft and insulates the electrical components preventing leakage and arcing.

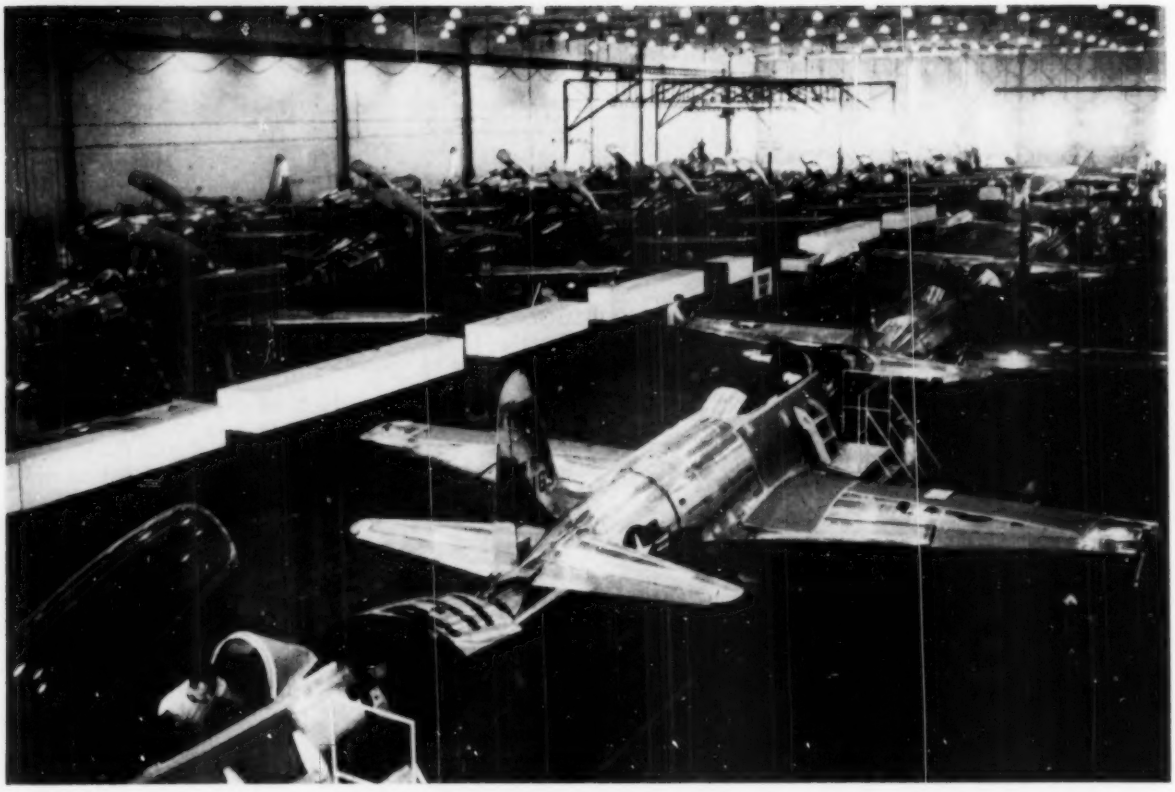


Chrysler K-310 Experimental Dream Car

EXPERIMENTAL K-310 SPORTS SEDAN was styled by Chrysler Corporation engineers in the United States and built in Turin, Italy, by Carrozzeria Ghia, a leading Italian body maker. Built as an experimental companion to Chrysler's K-310 engine developing 310 horsepower on premium gasoline, the K-310 car represents an American engineering idea of the sports car. Characteristically continental in design, it has low sweeping lines, a low flat hood and large wire wheels.

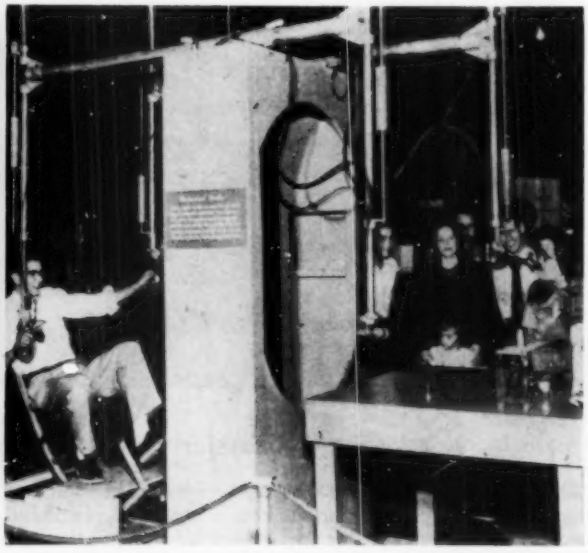
Only 50 inches high and with full head room, the sports car is built on a 125½ inch wheelbase and is 220½ inches in overall length. Its features include adjustable steering wheel, elevated directional and tail lights, a unique specially balanced fixture for lifting the spare tire from the trunk, and off-center front seat division for convenient access to the back seat.

Other features include a fully automatic transmission, electric window lifts, power steering and a new electric seat adjusting mechanism.

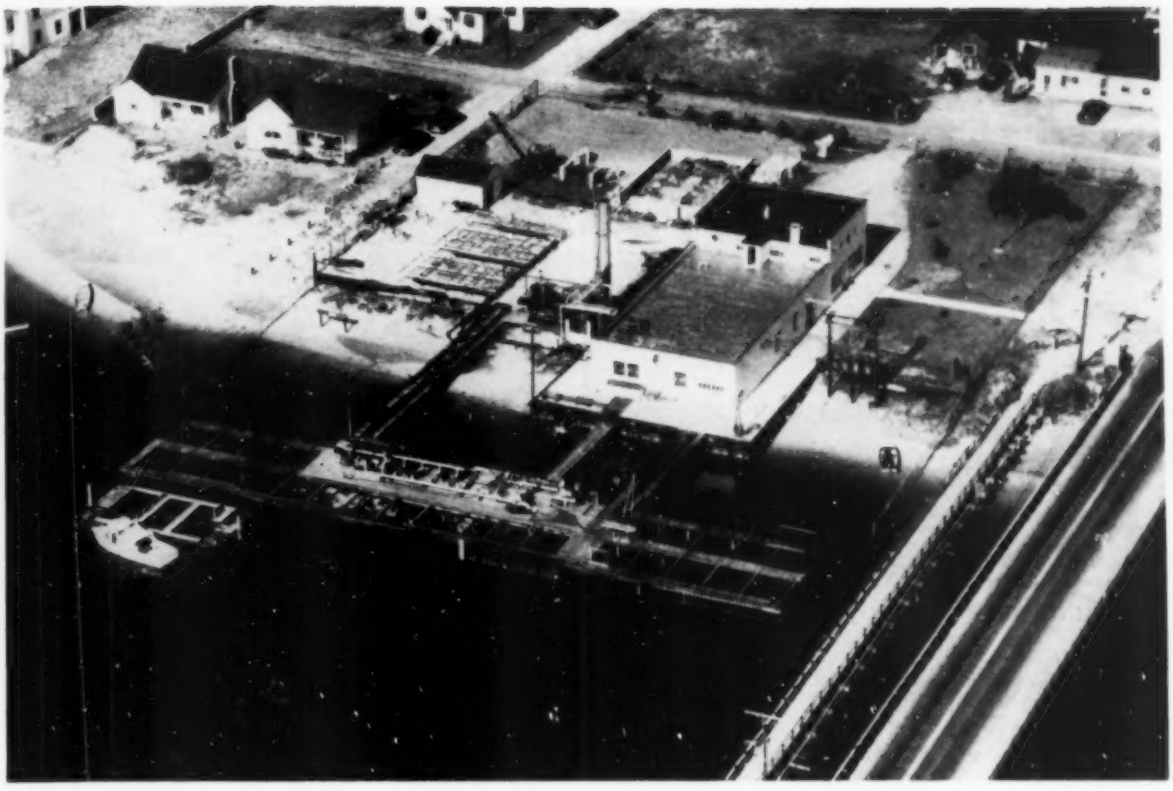


RIVER OF TWO-PLACE JET TRAINERS, used to teach modern techniques to U. S. Air Force and Navy pilots as well as airmen of several foreign countries, winds through trainer final assembly building at Lockheed Aircraft Corporation. Jet trainers ordered by U. S. services have been in production more than three years. They are going abroad to France, Greece, Canada, Turkey, Portugal and other areas yet to be announced. Production figures on the T-33's are a military secret as they transform fledgling airmen into jet pilots trained to the highspeed tempo of modern warfare.

BLAZING TORCHES slash into outmoded machinery in former powerhouse of Chrysler Corporation's Dodge Main Plant in Detroit to bolster vital U. S. defense supplies of scrap metal. The 41-year-old landmark, now replaced by newer powerhouse with larger capacity, will add more than 1,600,000 pounds of iron and steel to scrap bins when completely dismantled.

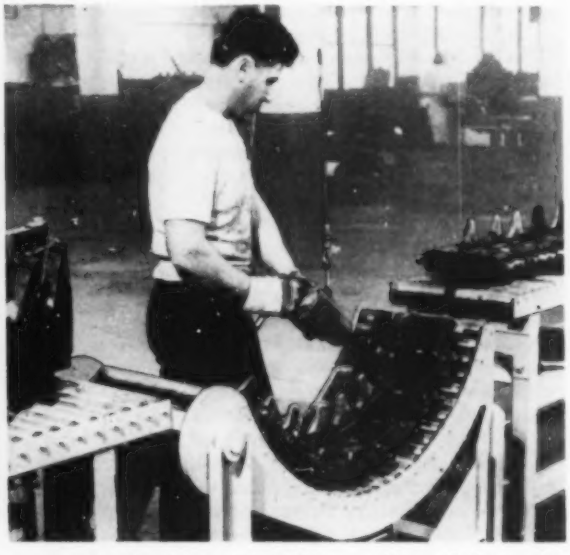


SEATED IN A CHAIR a dozen feet away, an operator manipulates a set of mechanical hands which are applying lipstick to the lips of the girl at the extreme right. In normal use, these mechanical hands enable workers on atomic energy projects at Oak Ridge, to handle radioisotopes at a safe distance. The device is part of a traveling exhibit from an Oak Ridge Museum.

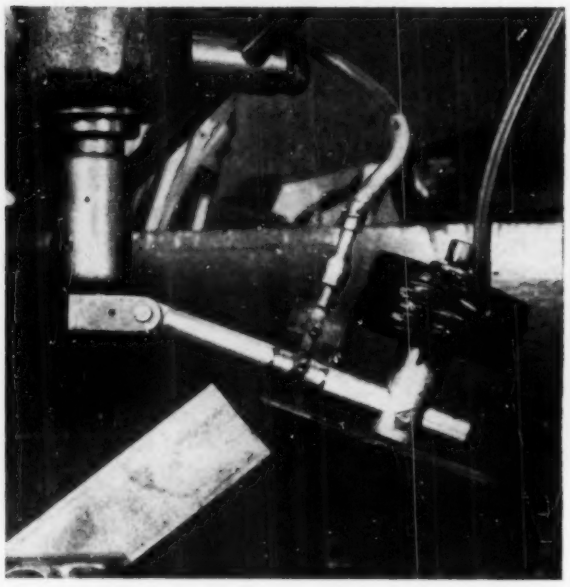


TWO STORY CONCRETE STRUCTURE being added to the Harbor Island Station of International Nickel Company's Kure Beach Project will house machine and carpenter shops, a marine museum, and a meeting room. A full size boiler plant, salt water evaporator and distillation unit will be installed in the present laboratory to study the effects of water treatment and design on corrosion and scaling of such units as used aboard ships. In the 16 years of its existence, the Harbor Island project has tested more than 20,00 specimens in sea water, 25,000 in sea atmosphere, and a somewhat smaller number in sea spray.

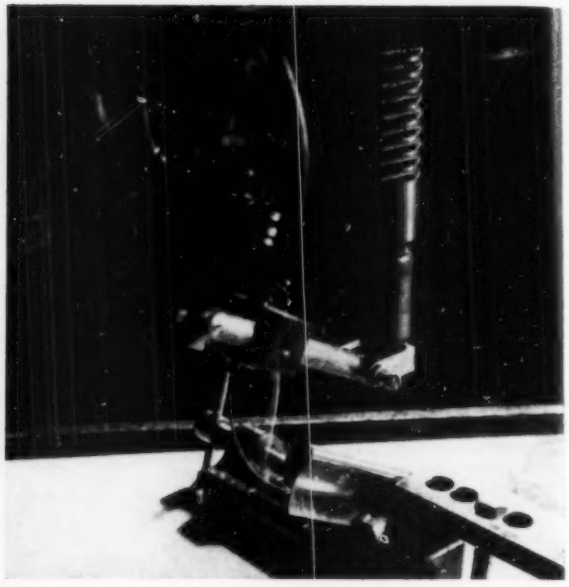
WET BLASTING EQUIPMENT used by Pratt and Whitney to remove hard, tough coatings of lead sulphate and lead oxide formed on experimental jet engine parts. This coating formed at extremely high temperatures must be completely removed prior to the parts inspecion under "black light." The unit was designed and custom-built by the Cro-Plate Company.



FIRST RUBBER TANK TRACKS are rolling off the production lines at the B. F. Goodrich Company's new track division. First shipment of tracks for the M-24 light tank have been sent to the ordnance depot for overseas destination. Patton, Sherman and Pershing tanks and high speed cargo carriers and gun motor carriages, will also get rubber tracks in the near future.



DRILLING APPARATUS CLOSE UP shows electrode (in work) vibrating apparatus and pivot bar. Tube connected to electrode carries cooling fluid into work piece. Electrode shaped to the desired radius rotates in the plane of the pivot bar.



SMOKE FROM HEATED COOLING FLUID curls upward during actual drilling operation even though drilling speeds are slow—in the neighborhood of three-quarters of an inch per hour. Spring reduces force electrode exerts on work piece.

New Drilling Technique Produces Curved Holes

A TECHNIQUE FOR DRILLING HOLES of any shape along a circular path has been developed by George A. Kemeny at the Research Laboratories of the Westinghouse Electric Corporation. This electric arc method was developed in order to place thermocouple junctions inside a casting at a location inaccessible by a single straight hole.

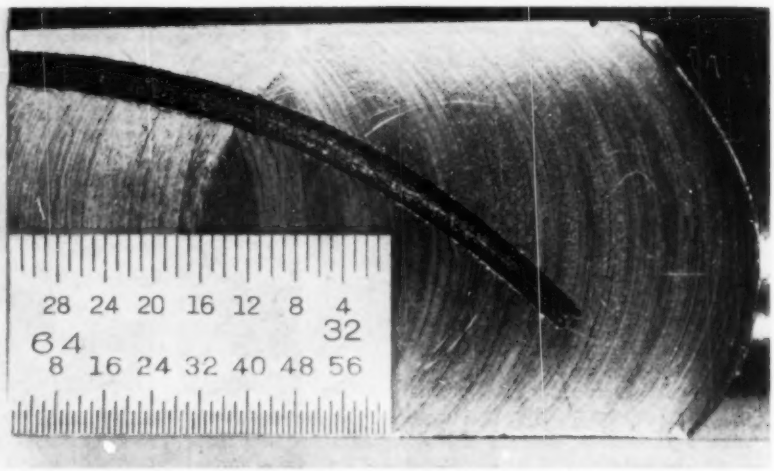
A disintegrating machine, the Thomas Metal Master, equipped with a specially adopted drilling rig supplied the electrical circuit and the cooling fluid. The metal master drills straight holes with an electric arc and the subsequent quenching of the molten metal by a cooling fluid passed through the center of the hole drilling electrode. The arc at the electrode tip is produced by vibrating the electrode.

In order to drill holes with a curved path, the electrode is shaped to the radius desired. Then a fixture to hold the electrode was designed so that the electrode vibrated along the path of its arc.

The vibrating mechanism consisted of a coil and a brass tube with a steel anvil that slides easily placed inside the anvil. When the coil is momentarily energized, the anvil is accelerated towards the top end of the brass tube and strikes this end with sufficient force to move the entire assembly, mounted on the pivot bar, a sufficient distance to break contact at the electrode. The anvil then returns to its downward position allowing the assembly to move downward and making contact again.

During the drilling operation, the amplitude of vibration and force available for breaking contact is varied to suit the particular operation by changing the voltage impressed on the coil. On occasion, the electrode spot welds itself to the work piece, and this method is used to increase the separation force and set the electrode free. The frequency of vibration is controlled by a geared variable speed motor with a cam to actuate a microswitch.

Drilling speed is slow with an average rate of $\frac{3}{4}$ inch per hour. The shape of the hole depends on the shape of the electrode. Different shapes can be obtained by substituting the desired shaped electrode for the circular electrode. Inspection of completed holes revealed that the hole size varied from about 0.093 in. near the entrance to 0.078 near the end. This tapering is apparently unavoidable in any hole drilled by the disintegration method.



CURVED HOLE is seen in detail by milling one side of the work piece. Hole size decreases as drilling continues deeper—a phenomenon unavoidable in any hole drilled by this method.

Ceramic Coatings Reach Volume Reduction Stage

ONE OF THE FIRST VOLUME ORDERS for ceramic coated metal parts that must withstand high operating temperatures has been obtained by Ryan Aeronautical Company. Ryan will produce approximately 600 exhaust systems for Pratt & Whitney Aircraft engines which will be used on Convair Models 240 and 340 transports.

The U. S. Bureau of Standards for several years has been trying to find a satisfactory frit for high temperature application and tested about 600 during this research. About two years ago it came up with a Bureau of Standards formula No. A-417 for high temperature application. This A-417 formula is available to anyone. Ryan's slip (Ryan's No. 331) is made from the formula. Raw material in frit 331:38 parts by weight flint or silicon dioxide, 56.53 parts by weight barium carbonated 11.5 boric acid. 7.14 calcium carbonate 2.5 beryllium oxide, 5.0 zinc oxide, for total 120.77 parts. This frit is then melted, shattered, ground to powder, and this formula used for making one gallon of slip: 700 grams of water. The whole is milled to fine consistency, screened and dipped on. In 1943 Ryan did considerable research in ceramics coating of mild steel for use in airplane exhaust systems. Out of that came World War II production of 500 exhaust systems for A-26 Douglas planes. At that time the goal was to substitute mild steel for stainless steel which then was in short supply. This was adequate on engines of 1,000 to 1,500 hp. Now however, with engines in excess of 3,000 hp it became necessary to process stainless steel to withstand the high temperature. The California Enameling Co. of Los Angeles fires the parts for Ryan at present.

NBS Develops Tape "Memory" For Computor

MAGNETIC TAPE, used as a recording medium, extends the problem-solving capacity of SEAC, the National Bureau of Standards Eastern Automatic computor by supplying a computor-controlled external auxiliary "memory". The new magnetic tape memory unit combines high speed starting, stopping, and reversing with notable mechanical simplicity. Two of the units are now in routine operation with SEAC, and plans call for adding two more.

In the new system, the magnetic tape rests on two smooth-surfaced rollers that rotate continuously but in opposite directions. Between these two rollers the tape passes through magnetic heads for recording, pickup, and erasing. When either of two control solenoids is energized, a low-inertia rubber-covered roller presses the tape against one of the smooth rollers. This quickly starts the tape moving in the desired direction. Tape inertia is kept low by letting each end fall in loose folds into a tank or bin. Each tank consists of two plates of glass spaced a little more than the width of the tape.

The speed and simplicity of the NBS system result from the successful elimination of reels and servomechanisms. Only two small masses need to be accelerated in starting the tape, the small jam roller and a few feet of tape hanging into the tank.

Several problems had to be solved to develop the tape memory mechanism. The tape tends to acquire an electrostatic charge as it is passing through the drive mechanism at higher speeds.

The charge causes the tape to cling to the walls of the tank as soon as it leaves the drive mechanism. If the charge is strong enough, the tape may continue to stick at the top of the tank until it backs up into the mechanism and is damaged by a sharp fold. The present solution—satisfactory at moderate speeds (up to 8 ft per sec)—is to ionize the air where the tape leaves the drive unit, using strips of alpha-emitting polonium. The ideal solution would probably be to make the tape base material sufficiently conductive, so that a charge could not collect. Experiment indicates that base material having a resistance of not more than a few megohms per unit square should be satisfactory.

A second limitation on the operating speed of the tape is imposed by the need to erase information from the tape. The necessary erase frequency increases as the tape speed increases. A tape speed of 16 feet per second, for instance, requires an erase frequency of several hundred kilocycles. Because of hysteresis losses, ordinary tape heads cannot operate at such high frequencies. New heads with powdered iron magnetic circuits, now being developed for use at much higher frequencies, should solve this problem. Meanwhile, it is always possible to erase the tape in a separate operation, at less than the normal running speed.

Flaws in the magnetic coating of commercially available tape impose a third limitation. Undetectable in ordinary audio work, they can reduce accuracy by missing a pulse.

THE MOST POWERFUL DIESEL-GEARED LOCOMOTIVE in revenue service in the world, a 55-ton 500 hp unit, has been built by the Hunslet Engine Co. Ltd. of England, for export to Peru. The locomotive is of the 0-8-0 type with a wheelbase of 13 ft 6 in., an axle load of 14 tons, a maximum tractive effort of 35,400 lb and a six-speed gearbox giving a top track speed of 33 mph.

•

LEAKAGE OF CURRENT in armatures of generators and motors in diesel-operated locomotives is effectively reduced through vacuum impregnation of these units with thermosetting resins. Vacuum impregnation is achieved by exhausting air from a chamber in which the armatures are placed. When a high vacuum has been reached, the chamber is flooded with liquid resinous insulating material. Due to the complete absence of air and moisture, the resin thoroughly penetrates all armature windings and assures permanent, efficient insulation supplementing the conventional wrapped or tubular covering.

•

NEWEST FORWARD MOVEMENT in naval lighter than air development is the ability to fly backwards. This trick, previously reserved for hummingbirds, is made possible for the ZPN, Navy's newest and world's largest blimp, through the use of Curtiss-Wright's "Zep-Props," which enable pilots to shift prop blade angle in flight without stopping engines. While extended wrong-way cruises are not practical, the ZPN can use reverse flight for quick stops, maneuvering and evasive tactics while carrying out its prime mission—submarine hunting.

•

PACKAGING ENGINEERS at the Army's Engineer Research and Development Laboratories, Fort Belvoir, Va., are installing newly-designed electronic equipment which will tell them what's happened to a packaged item and its cushioning material and wrapping when subjected to shock and vibration tests simulating air, rail or truck travel. This equipment will sense, measure, and record amplitudes and frequencies of shock and vibrations. It will record accelerations to 80 G's. Over-all frequency response is 2 to 500 cycles per second. Original "intelligence" is recorded on a moving tape, somewhat wider than used in operation of conventional tape recorders. Nine separate channels are available, with a tenth for time-interval marking.

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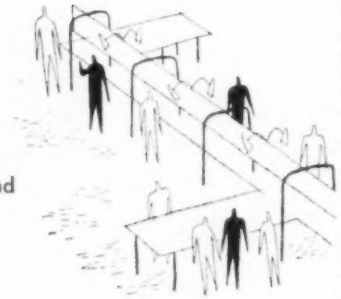

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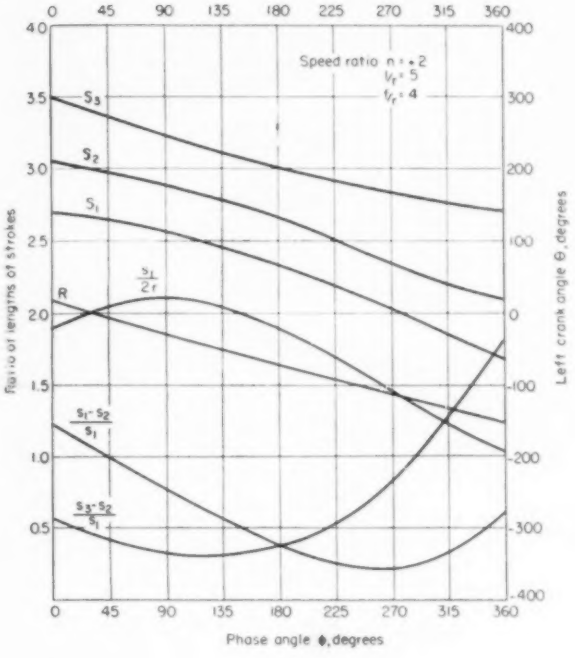
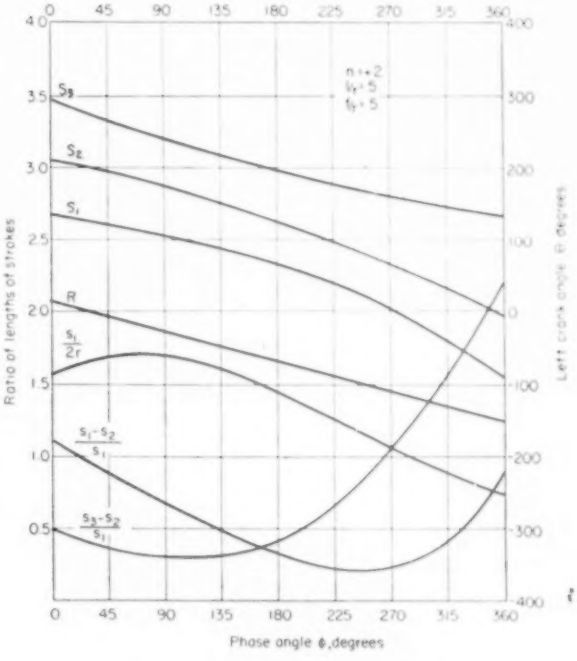
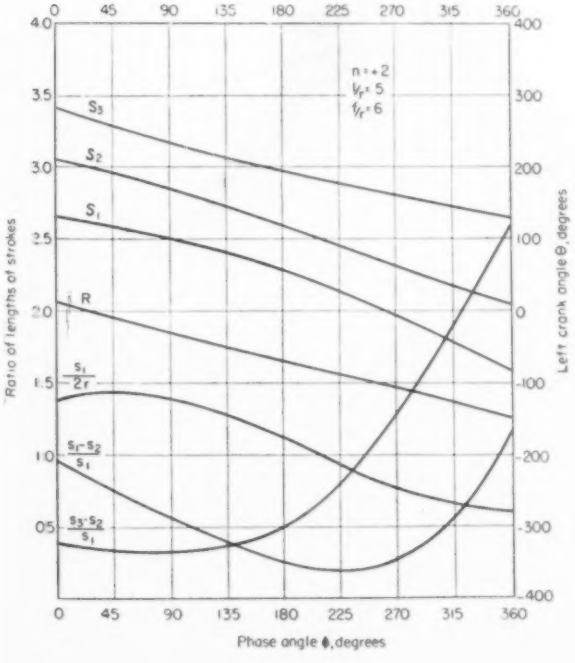
Design Charts for a Five-Bar Linkage

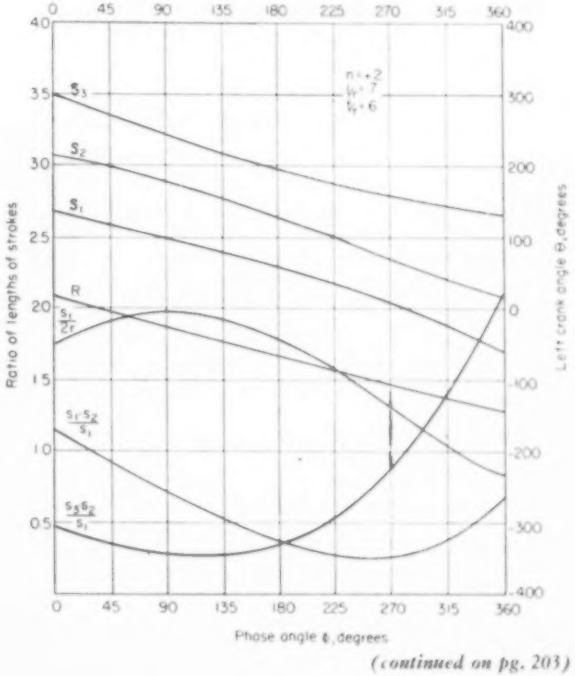
D. C. TAO and A. S. HALL, Purdue University

Purpose of these charts, as well as the details of construction, and an example of their application is given on page 175 of this issue.









(continued on pg. 203)

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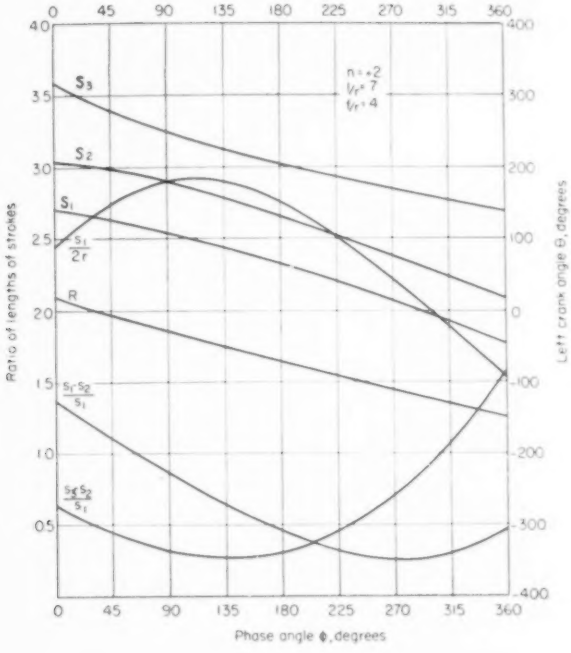
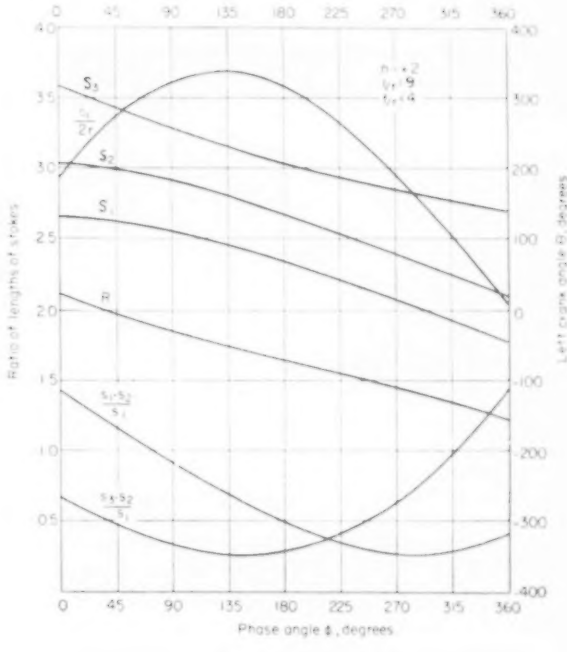
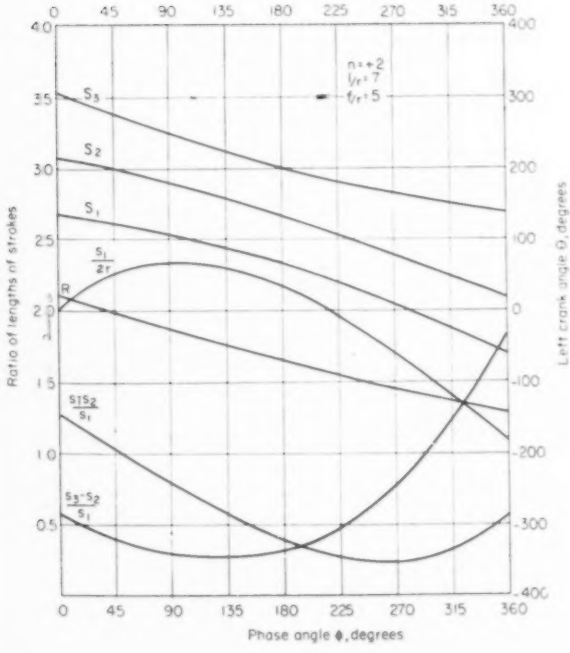
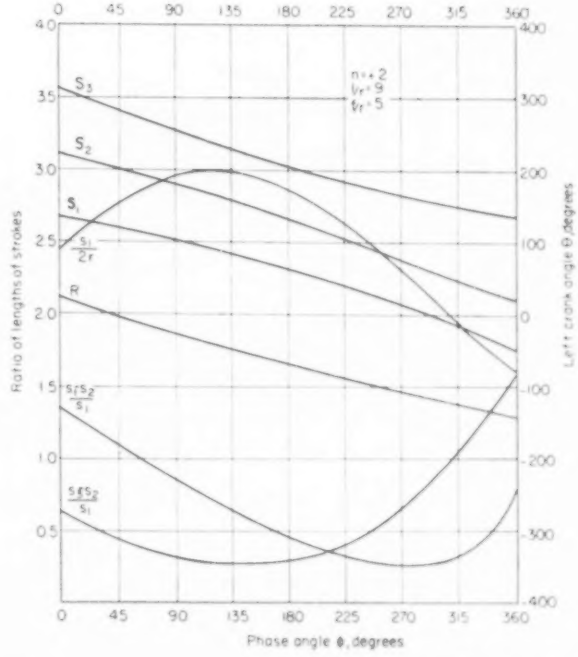
Design Charts for a Five-Bar Linkage (continued)









(continued on pg. 205)

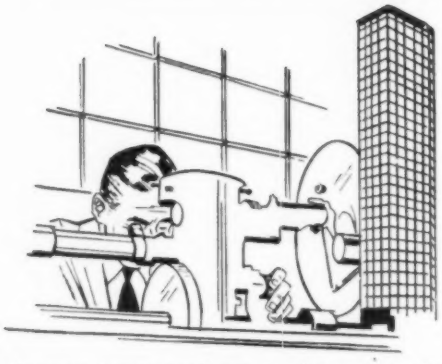
If you are starting from scratch...

Are you ready to put a new or redesigned product on the drawing board—perhaps with the idea that you will start production when materials are more plentiful?

steels are different

When you decide it's "time to design," our experienced engineers would like to demonstrate the advantages of modern sheet steels. You'll find them different—much different than those available to manufacturers a decade ago.

YOUR needs come first



Because Armco produces *special-purpose* sheet steels, our research men and mill technicians are alert to the needs of fabricators for better-looking and longer-lasting products.

wide variety of steels

This has resulted in a new "wardrobe" of coatings for many Armco sheet steels. Sheets coated with aluminum, special zinc coatings and special Bonderized surface treatments are a few.

Besides coated steels, solid Armco Stainless Steels are produced in a wide variety of grades and forms. Armco Enameling Iron is another.

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These special steels and durable stainless steels help underscore the advantages of sheet steels—their strength, resistance to impact, shock, abrasion and corrosion, and heat resistance.

For data on Armco Special-Purpose Sheet Steels, see our insert in Sweet's Catalog for Product Designers. Or write us for a copy.

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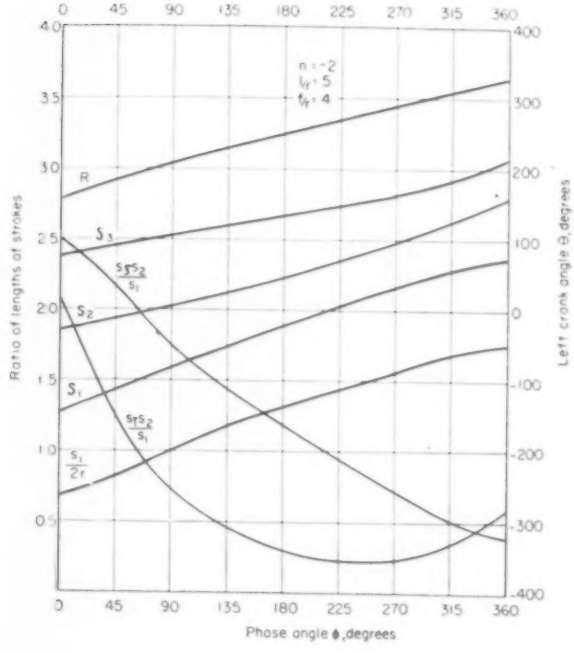
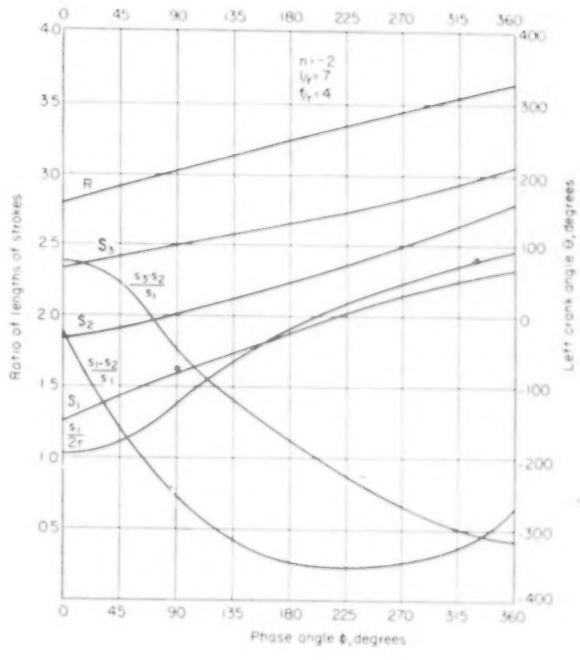
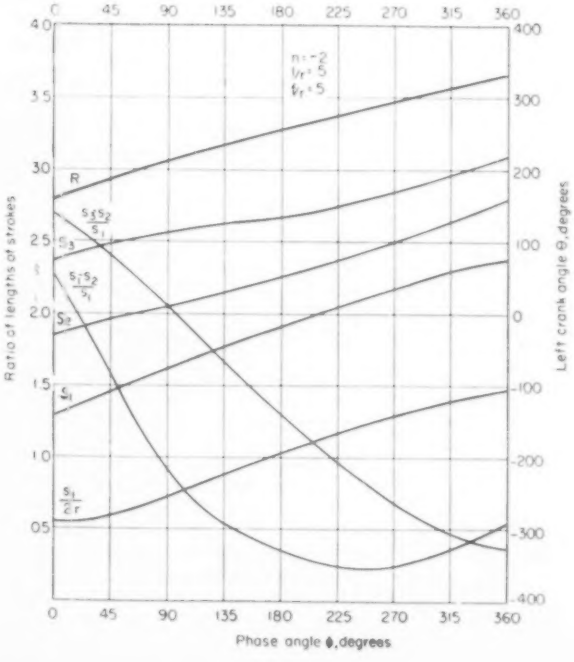
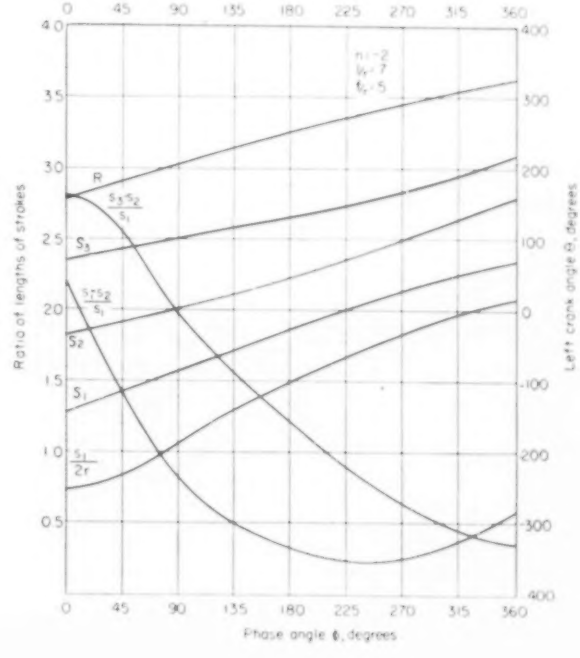
Design Charts for a Five-Bar Linkage (continued)

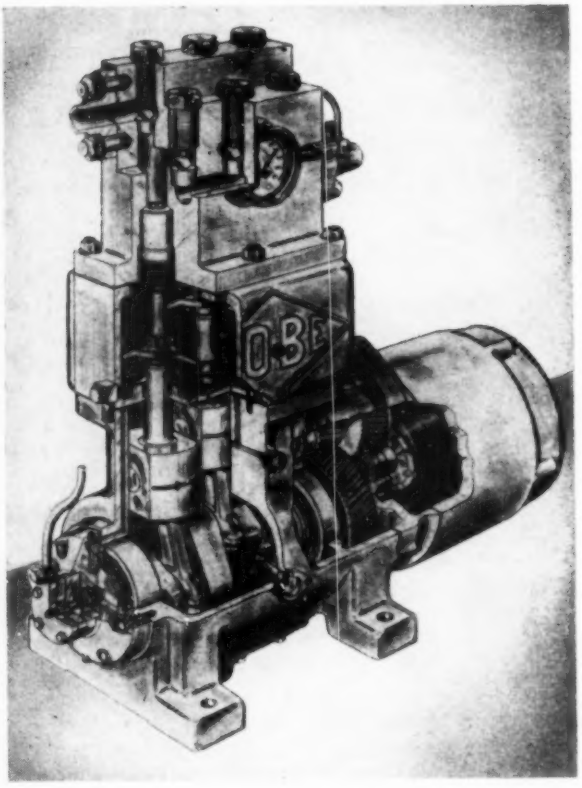








Hydraulic Power Unit In a Package



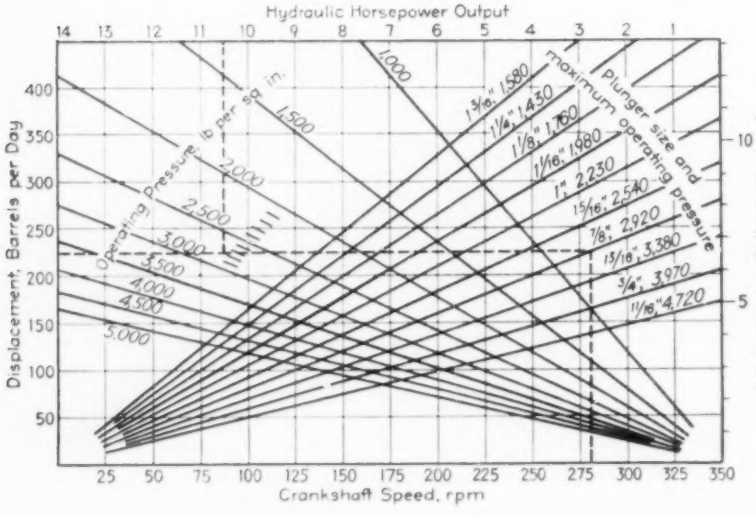
A compact high pressure triplex pump has recently been introduced for use as a heavy-duty packaged hydraulic power generator for all types of hydraulic power systems. The unit is available in 15 hp, 30 hp, and 50 hp sizes with pressure ratings up to 5,000 psi and displacement ratings up to 60 gpm. Special 10,000 psi and 20,000 psi heads are available.

The triplex is a three cylinder, vertical type, single acting reciprocating pump which operates much the same as an automotive type engine, except that the pistons are intaking and discharging fluid with the power supplied by a prime mover through the triplex crankshaft. In one revolution of the pump, each of the three pistons will intake and displace fluid from its cylinder. The amount of fluid displaced in one revolution depends on the size of the displacement plungers.

To permit a wide selection range of output volumes and operating pressures within the rated hp output of the triplexes, several different sizes of removable displacement plungers and liners are provided for each size pump. The liners have the same overall diameter but contain various sized displacement plungers. With this arrangement it is possible to vary the pressure-volume output relationship. Decreasing the plunger size raises the maximum allowable output pressure, and lowers the maximum allowable output volume. See operating chart below for specifications.

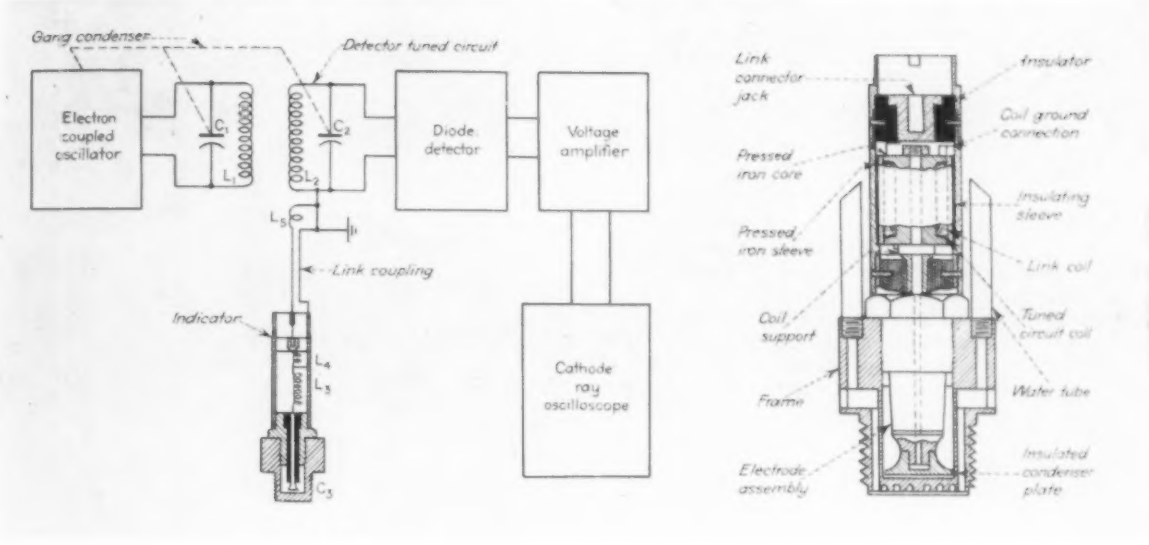
Features of the triplex pump include integral gears, available in a wide variety of ratios. The unit can be obtained with an integral, drip-proof electric motor drive which simplifies installation of this pump. Plungers and liners are interchangeable, which gives a variety of pressure-volume ratings for each unit. Lubrication is of the automotive type. A scavenger pump, located on the forward end of the shaft, returns any lubrication leakage to the system under a low pressure. Bearings are ball or roller type.

Kobe, Inc., 3010 E. Slauson Ave., Huntington Park, Calif.



GIVEN an operating pressure of 2,750 psi and a desired output of 225 bbl per day, find the plunger size, the pump crankshaft speed and the hydraulic hp output.

Referring to the chart: locate the displacement volume of 225 B/D on the left scale and extend a line to the 1 in.—2,920 operating pressure line. With vertical line downward from this point it will intersect with 281 on the rpm scale, showing the necessary speed for the desired volume. A line is extended vertically to the top scale from the intersection of the line representing 2,750 psi operating pressure. This shows a 10.5 hydraulic hp output for the given conditions. Maximum horsepower for the size 2 triplex pump is 12.5; the maximum pressure is 5,000 psi; the maximum crankshaft speed is 350 rpm; and the maximum volume is 450 B/D. For larger capacities the size 3 triplex pump is necessary.



Indicator Measures Static and Dynamic Pressures

A condenser type engine indicator has been developed which is capable of recording pressures as high as 20,000 psi, and as low as the force of blood in a human vein. This indicator may be used for research on automotive engines, fuels, transmissions, hydraulic steering mechanisms, the vibration characteristics of aircraft turbine blades at speeds up to 12,000 rpm and at temperatures up to 1,500 F. and other industrial problems.

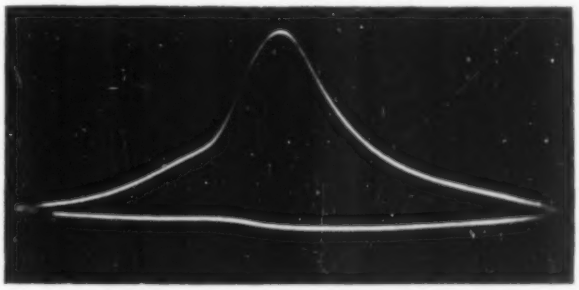
The indicator, as shown in the illustration, consists of a pick-up or transducer that can be screwed into the head of an automotive engine; the connecting cable permitting remote operation; and an electronic unit known as an oscillator detector may be applied to a cathode ray oscilloscope to enable observation or recording. Shown in the cutaway view of the pick-up is a center electrode, mounted in an electrode body in such a manner that it is both insulated and supported by means of a ceramic insulator. The lower end of this electrode is formed in the shape of an inverted mushroom which acts as an insulated condenser plate. The frame and the diaphragm are machined from Invar steel to minimize the effect of temperature changes in the diaphragm. Water cooling keeps the temperature of the indicator within range where the low thermal coefficient of Invar steel is realized.

A grounded plate is formed by the bottom portion of the body which is parallel to the insulated plate and separated from it by an air gap three thousandths of an inch thick. Pressure applied against the outside surface of the diaphragm causes it to bow, or deflect, resulting in a change of spacing between the plates of the condenser. This produces the change of capacity which is converted by the oscillator detector into a voltage for use as an input signal for the cathode ray oscilloscope. See illustration above.

This unit is essentially a displacement pick-up, and may be proved in a test with a tuning fork. Clamped close to the turning fork, a change in space between the blade and the insulated electrode will cause an input signal to the oscillator detector. The manner in which it vibrates may be observed on the oscilloscope.

A typical engine indicator diagram obtained is shown. This diagram shows the pressure fluctuations during the four strokes of a four cycle gasoline engine. Pressure is plotted on the vertical axis, and time is plotted on the horizontal axis. Compression starts at the left and follows toward the top. Ignition takes place at about half the peak pressure. Combustion is represented by the remainder of the up-sweeping curve, while the expansion stroke is shown by the decreasing trace at the upper right. To show pressure fluctuation during exhaust, the trace returns to the left of the diagram and follows the lower path.

General Motors Inc., Detroit, Mich.



THE FOUR STROKES of a four cycle gasoline engine show the pressure fluctuations in a typical engine indicator diagram.

CONTINUED ON PAGE 208

Dynamic Balancer Has Simple Operation

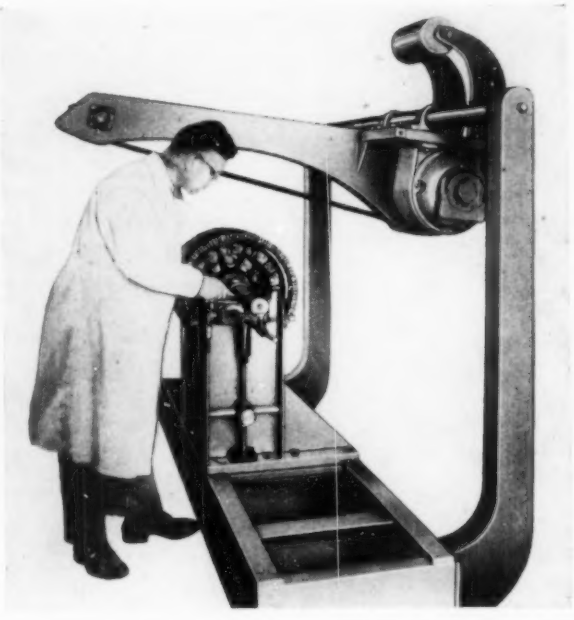
This universal dynamic balancer is a new machine that offers a simple method of putting armatures, rotors, pulleys, flywheels, gears, hubs, drums, and other rotating parts in true dynamic balance.

The part to be balanced is placed on the balancer with shafts resting on ball-bearing rollers and then rotated to determine the position of dynamic unbalance so that the corrective weights can be added.

The driving mechanism consists of an arm with a set of five V-belts driven by a 5 hp motor. Balanced to stand in up position normally, it is lowered by the operator until the belts touch the equipment to be rotated. A starting button is pushed and when the desired speed has been reached, the arm is raised. Rotation can be stopped almost immediately by lowering the arm and pushing a reverse button.

While rotating, the shafts are marked with pencil or crayon. With the unbalance causing the shaft to rotate off center, the markings will appear on one side, thus showing where weights should be added.

The balancer is 6 ft in height, requires 54 in. by 96 in. of floor space and weighs approximately 1,600 lb. It is capable of balancing equipment up to 48 in. in diameter, 4,000 lb, and 80 in. between the verticle standards.



Industrial Engineering Co., 122 E. 4th St., Davenport, Iowa

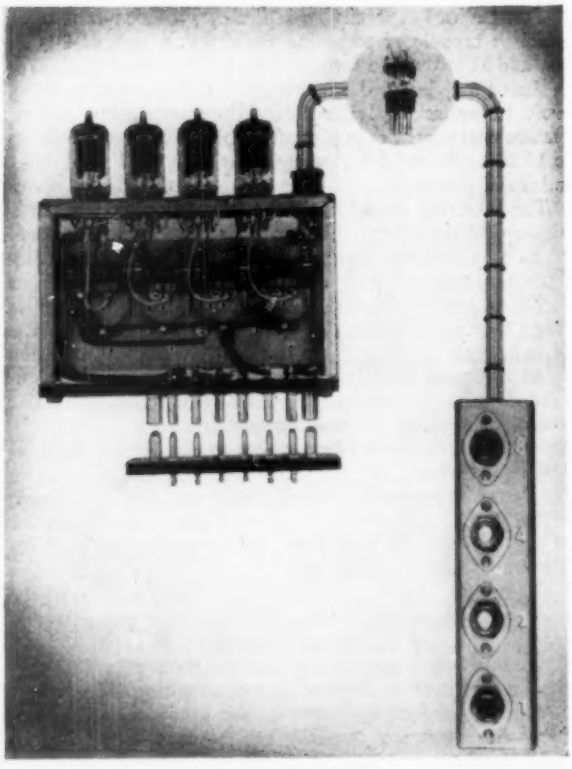
Miniature High Capacity Electronic Counter

A miniaturized version of the four-tube Electronic Counter Decade has been developed which is ⅓ smaller than the standard counter, and is available in two models which differ only in maximum counting capabilities. The model 12 is designed for counting at rates up to 130,000 counts per sec, and the model 13 for counting at rates up to 30,000 counts per second.

Among the features of the electronic counter decade, is the easy-to-read and dependable four-lamp decimal indication. Four large quarter-watt neon glow lamps, arranged in a 1-2-4-8 decimal coding, make it possible to read the counter under high ambient light conditions, wide angles, and at a distance where numbers can not be distinguished. Since each of the four lamps is directly connected to one of the four counting stages, the lamps also serve to indicate that the associated stages are functioning correctly; therefore tube failures can be detected and replaced. The counter stages are arranged so that the progression of count can not skip over a stage in which a tube failure has occurred.

The new miniaturized decades are available with either a remote panel-mounted four-lamp readout or with a small plug-in neon cluster on the decade frame for applications in which the indicators serve only for tube servicing.

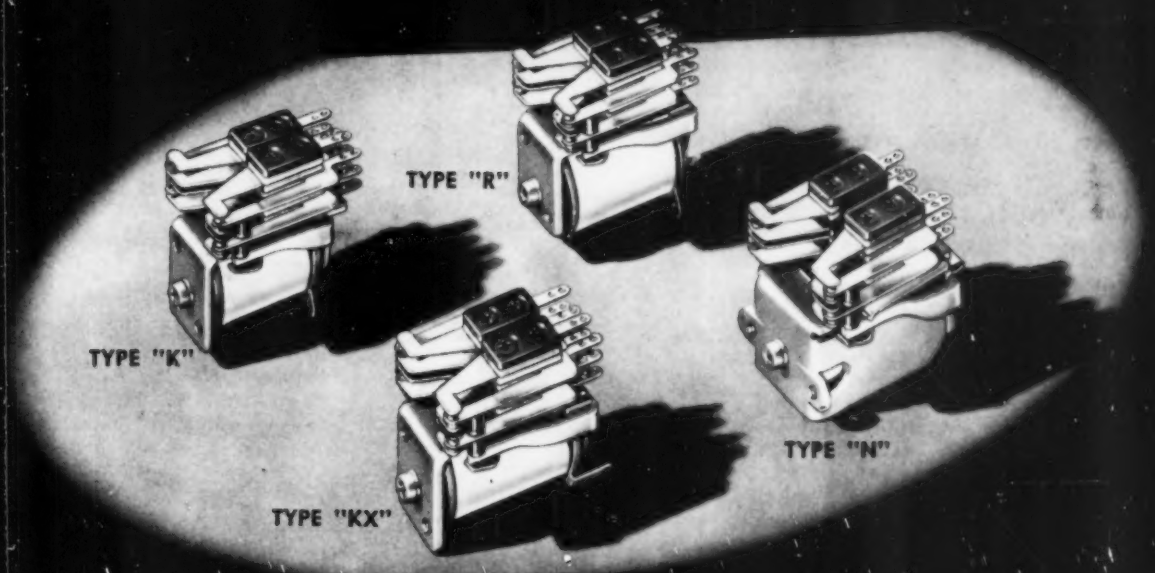
The size of the new unit is 6⅛ in. long, 6½ in. high, and 1⅛ in. wide including tubes. The decade is supplied with a silver-plated connector, assuring mechanical stability.



Potter Instrument Co., Inc., 115 Cutter Mill Rd., Great Neck, N. Y.

CONTINUED ON PAGE 210

CLARE RELAYS



Special Features

which make these relays first choice of exacting design engineers

THE CLARE Type "K" RELAY

Fast operation—adequate contact pressure—high resistance to shock and vibration—long life—small size—1½" x 1¼" x 13/16".

THE CLARE Type "KX" RELAY

Same features as Type "K" but adds greater operating range and increased sensitivity by use of a slightly longer coil which can be safely wound to a maximum resistance of 8000 ohms. Size: 1 3/64" x 1 3/32" x 1".

THE CLARE Type "R" RELAY

Same basic features as Type "K" but adds still further sensitivity and operating range to the Type "KX" by the use of a coil which is not only longer but of increased diameter to provide even greater winding space. Size: 1 7/16" x 1 3/64" x 1".

THE CLARE Type "N" RELAY

Same basic features as Type "K" but designed for operation on extremely low power. This results from a close-coupled magnetic circuit, generous use of magnetic iron and unusually efficient coil design. Size: 1 5/16" x 1 5/16" x 1 5/32".

● The Clare Type "K" Relay was the first of the famous CLARE line of small, lightweight, telephone-type relays. It is still the mainstay of design engineers who must have superior relays to operate in extremely small space.

Its fast operation, adequate contact pressure, high resistance to shock and vibration, long life and complete all-around dependability have met many complex requirements.

The other three relays shown here supply all these advantages of the Type "K", but each adds certain other features to meet such specifications as a greater operating range, greater sensitivity or operation on extremely low power. All except the type "N" retain the reed armature suspension of special alloy which engineers recognize as one of the subtler reasons for the superior performance of these small CLARE Relays.

Clare sales engineers are located in principal cities to give you first hand information on the entire line of CLARE Relays . . . all of them designed to meet the most exacting relay requirements. Call them or write to C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials, Ltd., Toronto 13. Cable Address: CLARELAY.

All relays available in hermetically sealed form

All of these four CLARE small relays are available enclosed in hermetically sealed steel containers. Connection diagrams are permanently imprinted on the base of the enclosure by silk screen process.

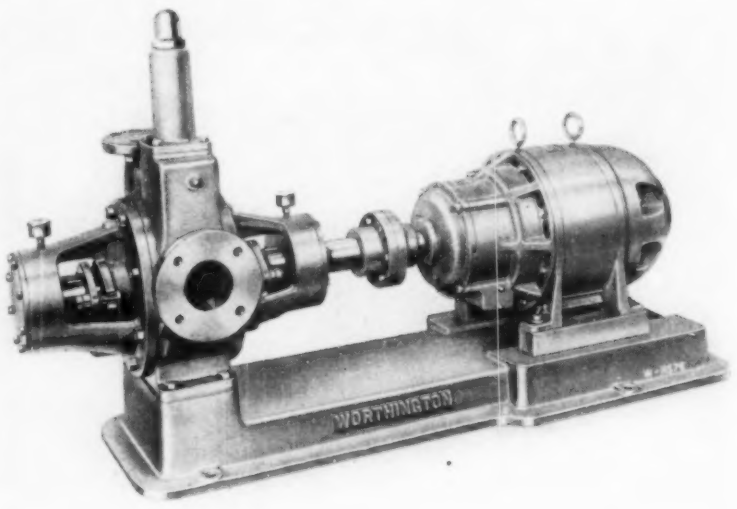
CLARE RELAYS

. . . First in the Industrial Field

Heavy Duty Rotary Vane Type Pump

To an existing line of rotary pumps has been added a new heavy duty, vane type rotary pump made in six models and eight sizes. Pipe openings range from 2 to 12 in. on the suction side, and from 2 to 10 in. on the discharge side. Capacity ranges of these pumps are from 25 to 1,000 gpm.

These pumps are positive displacement, sliding vane type in which the pressure of the liquid being pumped maintains the contact of the vanes against the liner. Features of the pump are: sturdy construction, simplicity in design, large continuous displacement, quietness of operation, and trouble-free service. Pumps are available in standard fitted construction, all bronze construction, or bronze-fitted construction, with or without integral relief valve. The vanes automatically compensate for wear, and all pumps are fitted with removable liners.



External bearing models enable pumps to handle non-lubricating, slightly abrasive or corrosive liquids without bearing failure at relatively high heads. Interchangeability of parts on different models permits stocking of fewer parts. All internal repairs can be made without breaking connections.

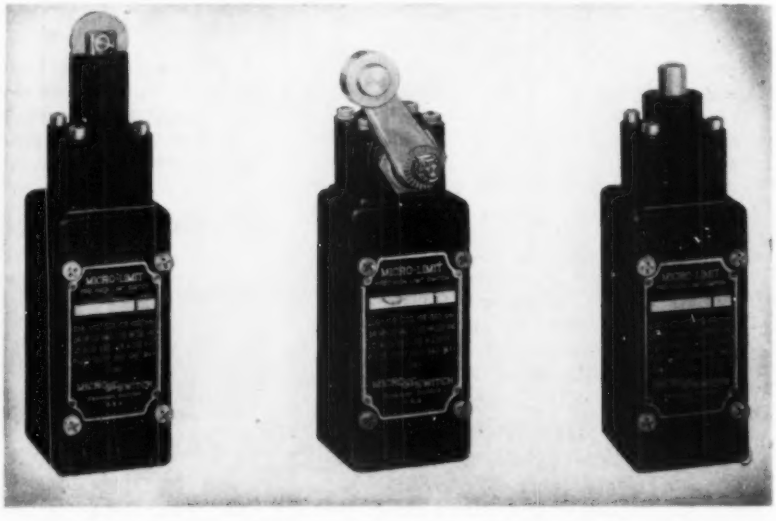
There are six models of the pump available. The model VE has external, non-lubricating bearings and is used for slightly abrasive and corrosive liquids. The model VEU is identical with the VE, except that it is equipped with an integral relief valve. The model VRU has internal anti-friction bearings and is used for heavy duty service on clean liquids. Suction and discharge lines are at right angles to each other. This model is equipped with an integral relief valve. The model VR is the same as the VRU but without the relief valve. The model VRHU is identical with the VRU except that both suction and discharge openings are in the same horizontal plane. Model VRH is the same as VRHU but without the relief valve. The VEU pump is shown.

Worthington Pump & Machinery Corp., Harrison, N. J.

New Actuators For Heavy Duty Limit Switches

To the type ML (micro-limit) line of heavy duty precision limit switches have been added two new types of actuators. The original type ML switch, 1ML1, has an adjustable roller arm actuator. The model 2ML1 has a straight plunger actuator and the model 5ML1 has a roller-plunger actuator. The roller-plunger actuator is adjustable 90 deg in either direction.

Underwriters' Laboratories list the type ML switches for 20 amps, 110, 220, or 460 v a-c; ½ amp, 115 v d-c; ¼ amp, 230 v d-c; ¾ hp, 220 v a-c. Pilot duty rating is 125 v a-c, 6 amp inrush; 480 v a-c, 1.5 amp normal, 15 amp inrush; 600 v a-c, 1.2 amp normal, 12 amp inrush. The switches meet NEMA requirements for non-ventilated enclosures type IV-IC1-1.2.



Micro Switch, Freeport, Ill.

CONTINUED ON PAGE 213

Small, Reluctance Type Synchronous Motor

A new small synchronous motor of the reluctance type has been developed without brushes, slip rings, rotating coils, or permanent magnets. The new motor maintains exact synchronous speed; starts and pulls into step at any rated frequency; is available with two, four, six, 10 or 12 poles for single or two-phase operation, and two, four or eight poles for three phase; will immediately pull into step after transient voltage drop or overload; is reversible with either single or polyphase operation, is installed with flange or special mountings; has speed ranges up to 40 to one and frequency range of 10 to 400 cycles.

The motor weighs 2½ lb and is available with open or special enclosures. When used as a signal generator it can supply any number of amplifiers. It can be used with manual setting to automatically maintain any selected speed for any number of prime movers with absolute stability. It is adaptable to high torque remote position control systems.

The ability of the motor to remain in step despite frequency variations makes it available for the following applications: driving sequence systems; driving high-speed recording instrument charts; driving large electric clocks; for basic elements in speed and position control systems; for signal generators in speed indicating, recording, and control systems.

Also, it may be used for both generators and motors in control systems where speed at the receiving end must equal the speed of the sending end, or some fixed multiple of it.

The motor can be built to operate continuously at any voltage below 250 v, single or polyphase.

A typical motor is 4 in. in dia by 2⅜ in. long, weighs 2.6 lb, and develops 8 oz-in. starting torque and 0.8 in. synchronous torque. Simplicity of construction provides high stock resistance and little maintenance.

Allis-Chalmers, Milwaukee, Wis. 1002 S. 70th St.

High Strength, Two Piece, Structural Fasteners

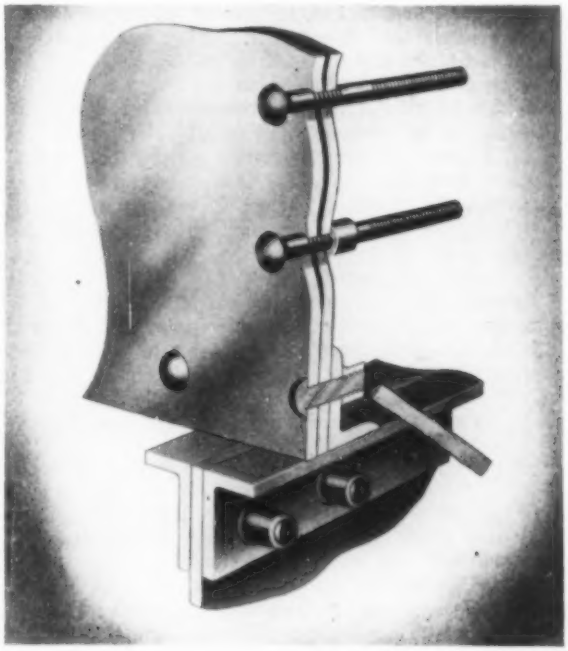
Lock Bolts, a new type of high strength, two piece structural fastener, weigh only 50 percent of an equivalent sized bolt and nut when installed. Consisting of a pin and a collar, the pin is inserted in the work from one side, and the collar slipped on the pin from the opposite side. A special pneumatic tool installs the lock bolt.

The manufacturer states that lock bolts can be installed almost twice as rapidly as conventional bolts and nuts, and that hole tolerances for an interference fit exceed those of AN bolts. This eliminates reaming. Strength values of the lock bolts are said to be equal to or greater than same-sized bolts.

On installation, the pneumatic tool engages serrated grooves in the shank of the pin. Exerting a pulling action on the pin, the tool simultaneously pushes the collar against the material, and clamps the material tightly together. The tool swages the collar into the pin groove, and breaks the pin flush with the collar. The clamping action will pull together a gap between sheets of as much as ¼ inch.

Lock bolts are manufactured in two series, aircraft and commercial. Aircraft series lock bolts are made of either 75ST aluminum alloy or heat-treated alloy steel; Commercial series of either 24ST aluminum or mild steel. Diameters range from $\frac{3}{16}$ in. to ⅜ in. and grip lengths from ⅛ in. to $1\frac{5}{16}$ inch. A variety of head styles is available.

The Cherry Rivet Co., Los Angeles, Calif.



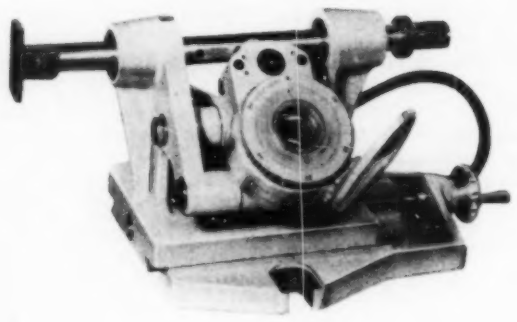
CONTINUED ON PAGE 214

Optical Cam Rise Gage Measures Cam Angles

The Cam Rise gaging device shown in the illustration is designed to measure cam contours (both angle and amount of eccentricity) by optical means, and to simplify and speed up accurate eccentricity measurements. The deviation in a cam surface at any angle of arc, from minimum to maximum radii, can be measured to ten thousandths of an inch. Reading is direct at normal eye distance, no focusing is necessary and errors inherent in mechanical gaging devices are eliminated. Because of its simplicity the chances for human error are reduced to a minimum. And since the optical system cannot be affected by wear, backlash, temperature changes, oil film or other factors, the system should retain its accuracy indefinitely. It eliminates errors possible in mechanical gaging methods.

For angular measurements the cam rise gage is used with a dividing head and tail stock to position the cam. The gage consists of a base for positioning and securing the instrument, a screw adjustment for moving the optical system into contact with the cam surface, a contact bar and cam follower that are held against the cam by adjustable weight tension, a scale, and a microscope.

A linear scale, engraved on the contact bar, is graduated from 0 to 3 in. in 50 thousandths of an inch. The microscope enlarges these divisions. Each 50 thousandths can be divided so that direct readings can be made to 0.0005 in., and movements of 0.00025 in. can be accurately estimated. The microscope is illuminated by a 6 volt bulb.



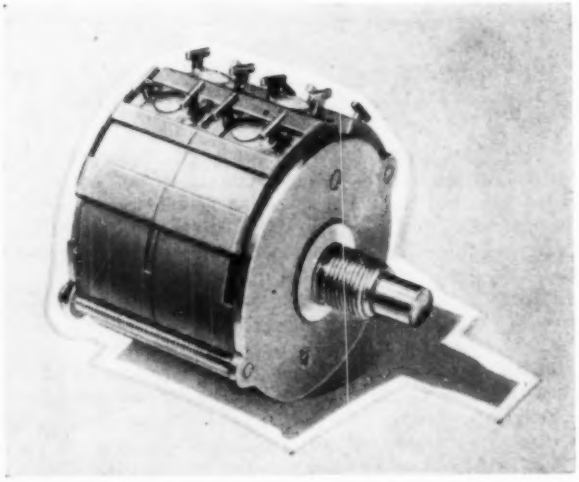
F. T. Griswold Mfg. Co., Wayne, Pa.

Multiple Control for Precision Electronic Units

A new potentiometer, known as series 42 A, gives simultaneous control of from two to twenty circuits and functions with high accuracy. Used mostly in electronic computing equipment, the unit is now offered in tandem assemblies.

The potentiometer is encased in a mineral-filled bakelite housing designed to lock together with similar units to form a single tandem assembly that is held together by metal end-plates and threaded tie rods. The contact arm of each unit can be adjusted on the common shaft that slips through all the tandem sections, to synchronize with reference to the common shaft or with the contact arms of other units. Mechanical rotation may be continuous or limited. Electrical rotation is 345 deg and can be adjusted to within plus or minus 1 degree. This can be increased to 359 deg for special requirements. There is no backlash or play in any of the tandem units. Also, tracking of all units is said to be assured.

Resistance range of each potentiometer is 100 to 100,000 ohms for linear windings. Tapered windings are also available. Linear controls are rated at 3 watts, while tapered controls depend on the nature of their taper. Standard overall resistance tolerance is plus or minus 5 percent. The ratio of voltage at any point on the series 42 A potentiometer to the total impressed voltage can be kept within 0.5 percent of the theoretically correct value.



Clarostat Mfg. Co., Inc., Dover, New Hampshire

THE USE OF a new time saving graphite lead drawing instrument using No. 9040 flat, very thin drawing lead permits the drawing of continuous straight lines of positive uniformity. The lead is available in degrees HB, F, H, 2 H through 9 H. A. W. Faber-Castell Pencil Co., Newark, N. J.

ONLY 0.003 IN. THICK, a new high-heat insulation known as Silicone Resin coated Novabestos has been developed which may be used at operating temperatures of 355 F. It is composed of 97 percent pure asbestos and 3 percent organic material. Irvington Varnish and Insulator Co., 6 Argyle Terrace, Irvington 11, N. J.

CONTINUED ON PAGE 216

Key to better piping design . . . your easy-to-use CRANE Catalog

You can design better piping into any product . . . faster . . . when you specify from your Crane Catalog. Here, between two covers, you'll find the world's most complete assortment of quality piping materials—carefully arranged for convenient selection. And for every piping item there's a full listing of recommended services; complete design, material, and construction details; plus helpful, easy-to-use pressure and temperature rating tables. In addition, your Crane Catalog answers general engineering questions connected with designing efficient piping systems.

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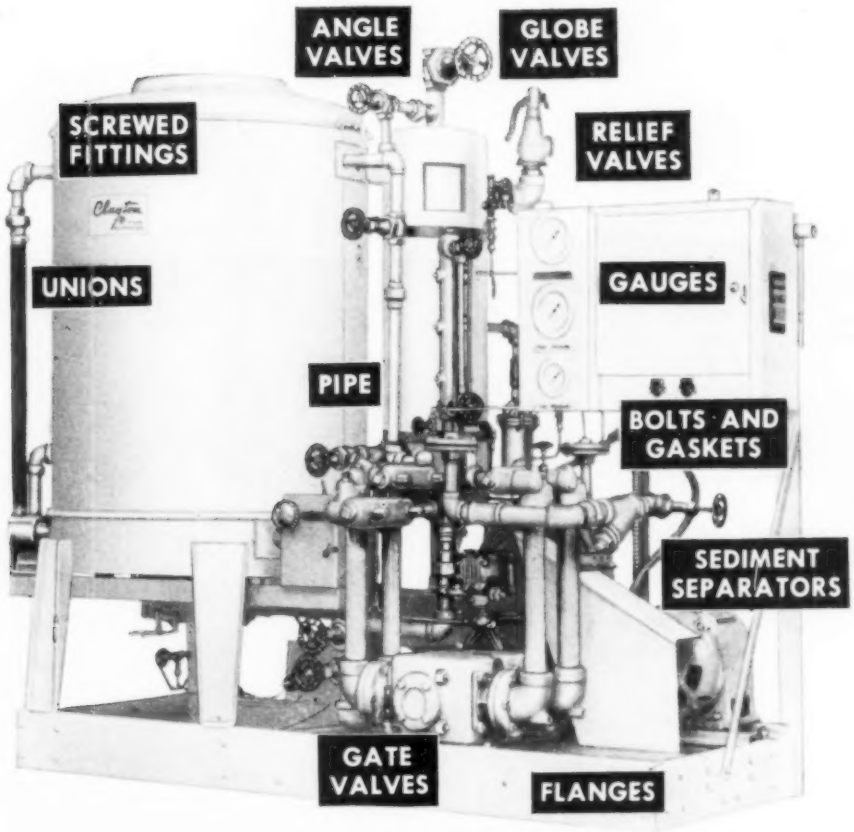
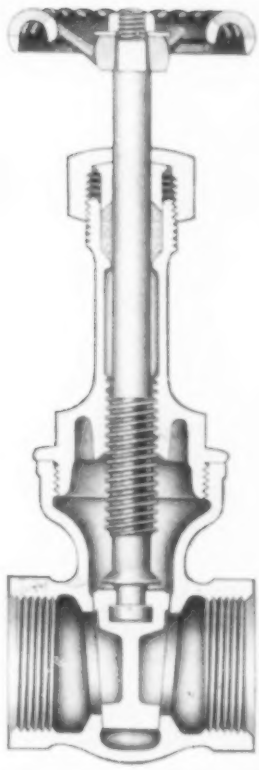
FOR A BIGGER SELECTION OF BETTER PIPING . . . CHECK THE BROAD CRANE LINE



Steam Generator by Clayton Manufacturing Company, El Monte, California



FOR RUGGED, DEPENDABLE service on steam, water, oil and gas lines—Crane recommends 150-Pound Brass Gate Valves with accurately guided solid wedge disc. Tight stem seal assured by high quality stuffing box packing and gland; can be repacked under pressure. Rising or Non-Rising Stem; screwed or flanged ends. Sizes: ¼ to 3-inch. See your No. 49 Crane Catalog, page 17.

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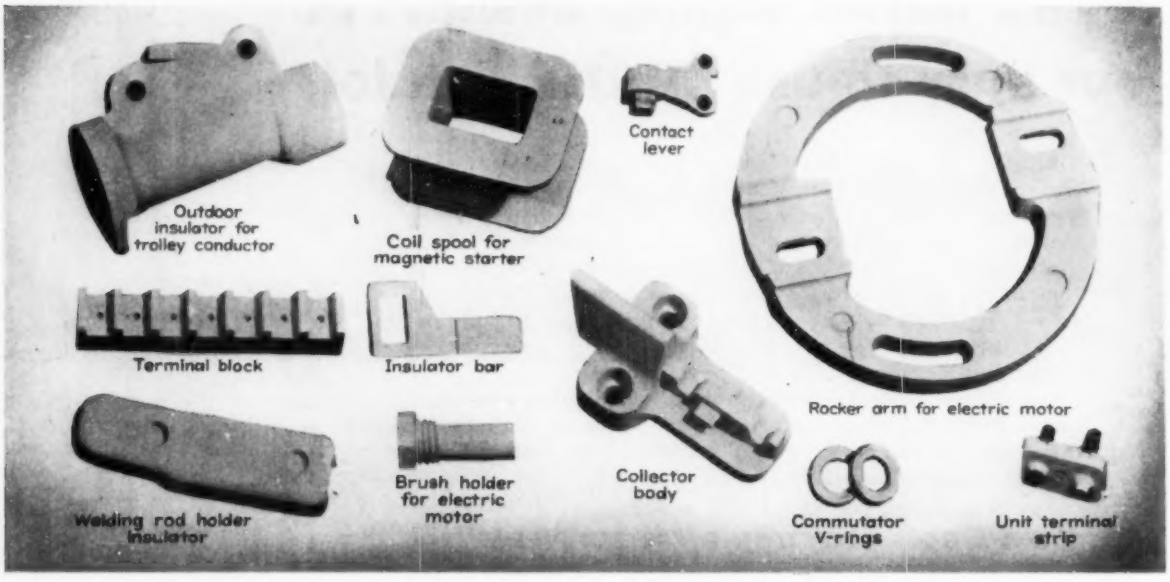
VALVES • FITTINGS • PIPE • PLUMBING • HEATING



Reinforced Plastic With High Impact Strength

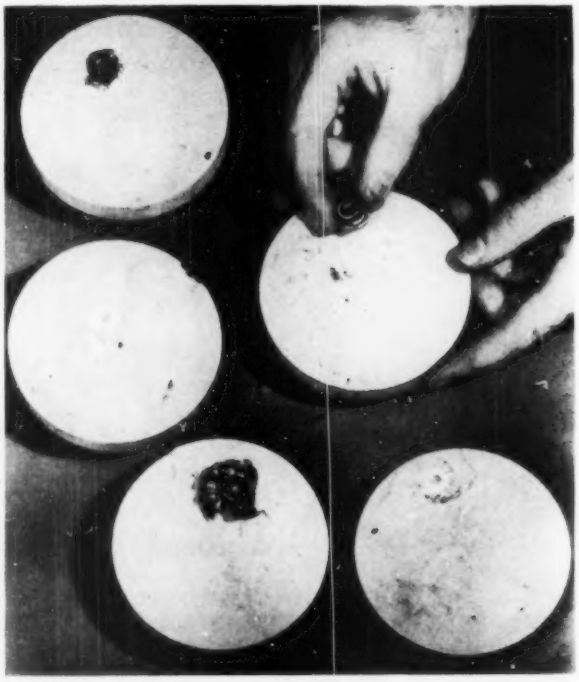
Plaskon Type 440 Alkyd, a new high impact glass filled thermosetting molding material, is supplied as irregular pieces of matted glass fibers combined with resin binders. Among its characteristics in molded form are: high impact strength; dimensional stability; good electrical properties; high heat distortion temperature. The new compound is supplied to molders as a complete resin and glass fiber mixture. It may be preformed, but no pre-heating is necessary because of its fast curing properties. Reinforced alkyd can be either straight compression, or transfer molded. The new alkyd material will be sold in two forms, Plaskon alkyds 440 and 442, with the latter having good flame resistance.

For mechanical properties, the Izod impact strength values usually range from 12-24 ft-lb per inch of notch, although both lower and higher values are obtainable, depending on molding technique. Using conventional testing methods, the flexual strength indicates average values of 14,000-17,000 lb per sq inch. Because of the reinforcing glass fibers, residual strength is still present after the initial cracking. Nominal compressive strength values of 20,000 to 25,000 lb per sq in. have been obtained. The modulus of elasticity is 1,600,000-2,000,000 psi. Because of the high impact strength, type 440 is said to be almost as strong after failure from high stresses has taken place as it was originally; therefore, in many cases local failure only relieves the stresses and the part is just as serviceable as before. When local failure takes place there is no tendency for cracks to spread under moderate stresses. Machinability is good if carboloy tools or diamond wheels are used.

The electrical properties are: dielectric constant for 60 cyc is 5.2-6.0, and one megacycle is 4.0-4.5; dissipation factor for 60 cyc is 0.023-0.024, and for one megacycle—0.019-0.020. The results of arc resistance tests for the ASTM method varies from 15 to over 180 seconds, while other types of tests have reportedly shown up well. The manufacturers suggest that the suitability of plaskon 440 for applications requiring arc resistance should be determined by actual evaluation of the part in question.

Other properties: coefficient of thermal expansion, 10×10^{-6} to 30×10^{-6} in./in./F; thermal conductivity, 8×10^{-4} to 12×10^{-4} cal/sec/cm^2/1 C.

Libby-Owens-Ford Glass Co., Toledo 6, Ohio



SAMPLE DISKS of the reinforced fiber glass plastic that received hits from Colt .45 automatic fired at 30 and 50 feet.

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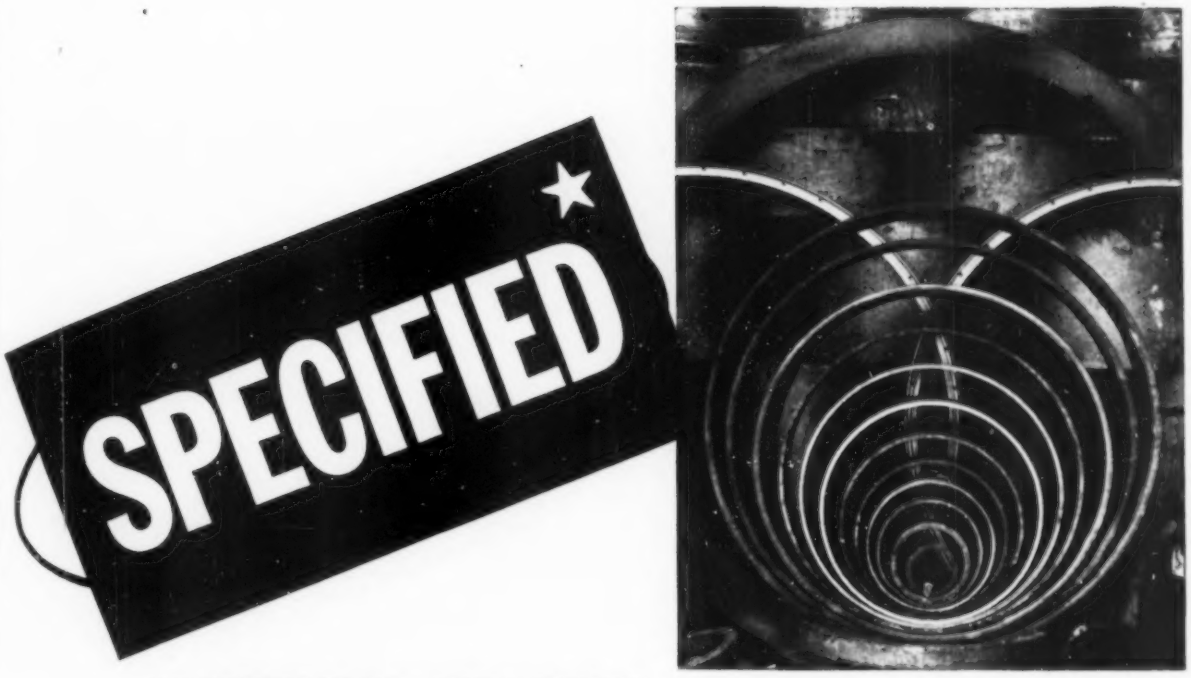

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★ *Specified because*

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- Close dimensional tolerances are held, thereby reducing the amount of excess material and minimizing machining.
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Send us your specifications for prompt quotation . . .
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THE AMERICAN WELDING & MANUFACTURING CO. · 140 DIETZ ROAD · WARREN, OHIO

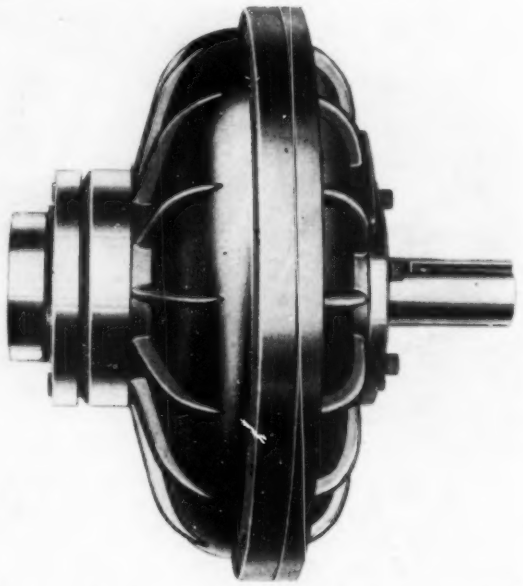
Fluid Drive Units for Difficult Starting

Difficult starting with a heavy load is made easy with three new liquid drive units. The three couplings available are designated as the TF, TH, and TS units. The TH design is of rugged steel construction and is arranged for direct hub mounting on an electric motor shaft. There are five standard arrangements available to allow for varying machine design requirements. Ample bearings and a bellows type of shaft seal are provided, all of which are lubricated by the oil in the liquid drive. This unit has a capacity range of from 10 hp at 870 rpm to 75 hp at 1800 rpm.

The TS design is of aluminum construction and available in capacities from 1½ hp at 1200 rpm to 24 hp at 1800 rpm. These units are designed with an output sheave which rides over the position occupied by the motor shaft, thus eliminating all unnecessary overhang. The sheaves are available from a 2-groove B section unit on the smaller couplings to a 7-groove B section unit on the larger couplings. All bearings and shaft seal are lubricated by the oil in the liquid drive.

The TF design units are made of aluminum and are available in capacities from ½ hp at 1200 rpm to 25 hp at 1800 rpm. They are designed for direct mounting on standard NEMA frame electric motor shafts. Under normal operating conditions, the three types of couplings will operate at approximately 3 percent slip, resulting in an efficiency rating of 97 percent.

Some of the applications of the liquid drive units are: cranes, hoists, trolleys, car pullers and winches, centrifugals, cable stranders, conveyors, mixers, and agitators. Shown in the illustration is the TF unit.



Liquid Drive Corp., Holly, Michigan

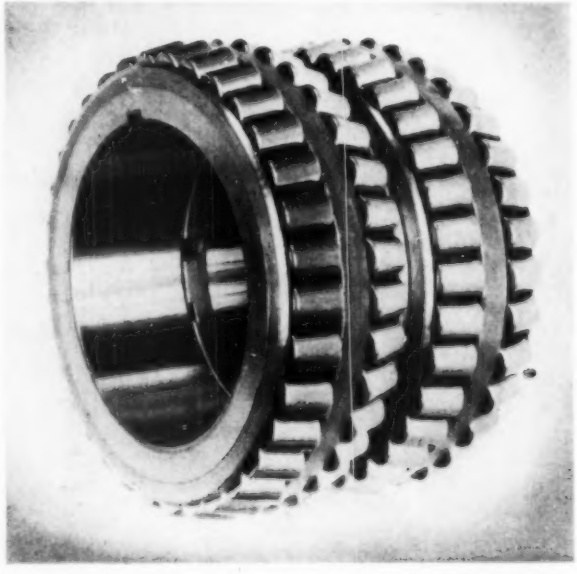
New Size Range for Antifriction Bearings

A new size range has been added to a standard line of full roll one, two, and four row tapered antifriction bearings. Single row bearings are available in sizes from 2 to 20 in. O.D. and four-row bearings from 6 to 20 in. O.D. These new full-roll units have been engineered for use in rod, bar and strip mills, pinion stands, gear drives, piercing mills, table rolls, reels, straighteners, cranes and other heavy metal-working machinery. These bearings are said to speed roll changes, decrease power consumption, reduce lubrication and maintenance costs, increase general overall efficiency, and to be superior for heavy duty service.

The four-roll bearing illustrated, measures 10¾ in. I.D., 15¾ in. O.D., and 10 in. wide. This bearing is manufactured to AFBMA standards, with the bore held to 0.001-in. and the O.D. to 0.002-in. tolerance, and is made entirely of chrome-nickel steel. At 500 rpm, it has a 126,000-lb radial capacity and 24,250-lb thrust.

The distribution of the load over a full complement of tapered rolls assures smooth operation at full radial and thrust capacities. Because of the close spacing of the rolls, possible deflection in cone and cup members is reduced to a minimum. Positive alignment is achieved by contact of the tapered rolls with the high back rib which is an integral part of the cone.

The manufacturers claim the bearings have a maximum number of rolls with high capacity, rigidity, and long life.



Tyson Bearing Corp., 1296 Oberlin Rd., Massillon, Ohio

CONTINUED ON PAGE 220

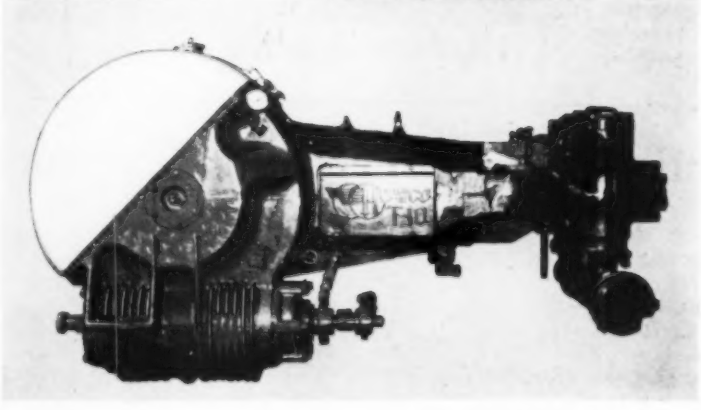
Greater Load Capacity of

ORANGE *"STAGGERED"* ROLLER BEARINGS

— meets severe requirements in crankshafts of

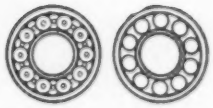
Halliburton

TRIPLEX PUMPS



Halliburton Triplex Pumps are capable of developing 12,000 p.s.i. pressure. They are used for pumping cement, mud, water, acid and other fluids used in servicing oil wells. The manufacturer, Halliburton Oil Well Cementing Co., Duncan, Okla., has found Orange Staggered Roller Bearings best suited for the exacting operating conditions of these high pressure pumps.

THE outstanding success of Orange Staggered Roller Bearings in heavily loaded or highly-stressed applications, comes from their unique staggered roller design. (See lower left). As a result, they carry higher loads than conventional bearings. You can design to carry the desired load with smaller size "Staggered" bearings. Or, replace present bearings, size for size, and gain extra load capacity, added safety and longer service life. Orange "Staggered" Roller Bearings are fully interchangeable with conventional bearings in the 200 and 300 series and the 5200 and 5300 series.



Illustrations show how load is divided over many short rolls, instead of a few full length rolls. End view of Staggered bearing and conventional bearing, show how staggered roller design brings a multiplicity of contact points within the loaded zone.

Write for Engineering Data Book on "Staggered" Roller Bearings, showing construction, dimensions, capacities, application data, etc.

ORANGE ROLLER BEARING CO., INC., 551 Main Street, Orange, N. J.

Plug-in Type Low Voltage Transformer

The 71-A variac transformer is a ready-to-use, enclosed package with attached cord and plug for 115 v, 60 cycle input, and a pair of Type 938 Binding Posts to deliver 0 to 16 v output.

The transformer is rated for 5 amp continuous duty, with a conservative 50 C internal temperature rise and an output regulation drop of less than 3 v at full setting.

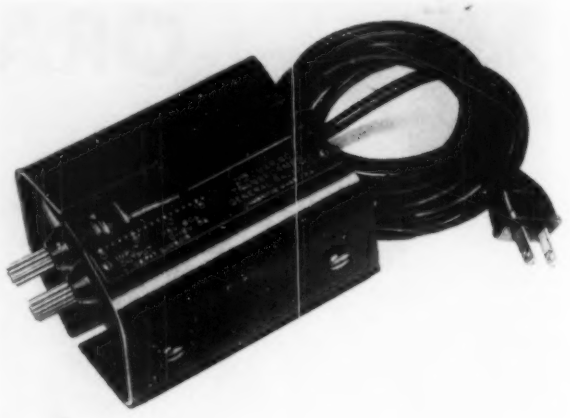
The basic unit is composed of two layer-wound primary coils on opposite legs of a conventional stack of L-type laminations plus two single-layer secondary coils wound over each of the primaries. The insulation between coils and to the core will withstand a 1250-v breakdown test. The secondaries are tapped by a unique arrangement of two standard Variac brushes on a single aluminum radiator, which permits direct connections of the coils to both line and load without slip rings.

The simple, rugged enclosure is largely made up of two heavy aluminum U pieces, which are held so as to provide a ¼ in. mounting slot at the bottom and a guiding track for the slider carrying radiator and brushes at the top. This slider assembly is the only moving part.

The mounting slot permits securing the unit to a wall, out of working space, or into a device as a permanent component.

The slider track is calibrated in open-circuit voltage for ready reference.

The limited voltage range makes this transformer particularly safe for experimental work, the isolated secondary permits its use in floating circuits, and the continuous adjustment is convenient in compensating for voltage fluctuation or in determining performance over a voltage range. Specifications: Input Voltage 115 v; Output Current 5 amp maximum; Output Voltage 0-16 v open circuit, 0-13 v at 5 amp; No-Load Loss, Less than 5 watts; Dimensions, (Length) 5½ x (width) 3⅝ x (height) 3¼ in., overall; Net Weight 4 lb. The unit has a wide range of application.



General Radio Co., 275 Massachusetts Ave., Cambridge 29, Mass.

Two Units Permanently Record Alternating Current

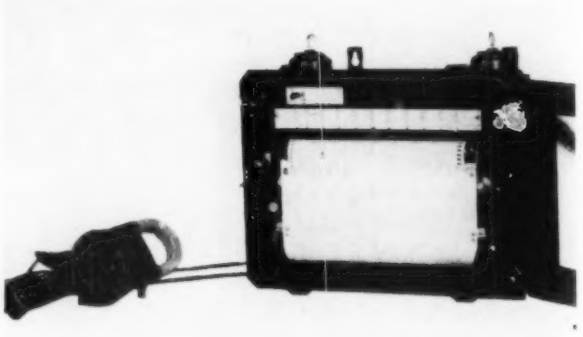
Designed to check on and make a permanent record of the use of a-c and circuit reactions, the recording ammeter used portably with a clamp ammeter unit can be used to cover all operations within a power, manufacturing or processing plant. The records obtained can reveal proper or improper handling of plant equipment, detect unwarranted use of power, and discover unnecessary waste of production line time by checking the starting and ending time of operating equipment.

The new modified model 633 clamp unit can be used for making rapid a-c measurements on either insulated or non-insulated conductors. It functions on the magnetic induction principle. The trigger-action clamping jaw is hooked onto the conductor and current is induced in a winding on the magnetic circuit of the clamping jaw. By means of a rectifier network contained within the instrument, the induced a-c is rectified into d-c which is supplied to the recording ammeter.

The instrument can be used with an extension cable several hundred feet long to connect to the recorder. The laminated clamping jaws are insulated with a heavy rubber sleeve which withstands a breakdown test of 5,000 v a-c, and can accommodate conductors up to 2 in. diameter.

When used on commercial sine wave of frequencies between 50 and 70 cyc, the instrument is said to have an accuracy of within 3 percent. The slight effect of the position of the conductor is included in the 3 percent overall accuracy.

The clamp pick up, which has terminals and a range selector switch on the face of the instrument instead of a dial, is compensated for temperature variations. The influence of temperature changes from 32 F to 110 F (0-43 C), will affect its accuracy less than 1 percent. The device is used with a converter and a transformer for permanent use.



Tagliabue Instruments Div., 614 Frelinghuysen Ave., Newark, N. J.

CONTINUED ON PAGE 222

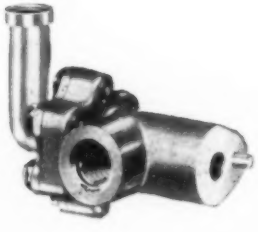
BARCO

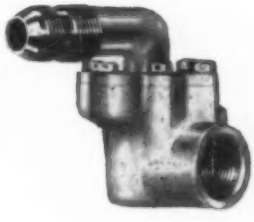
High Pressure Hydraulic SWIVEL JOINTS and Assemblies

FOR *compact, smooth-acting, trouble-free* movable joints in high pressure hydraulic piping or tubing SPECIFY BARCO! Here's why: Barco's exclusive design provides *side flexibility* to allow for piping misalignment and to PREVENT BINDING. *Only Barco offers this important advantage.*

Barco High Pressure Hydraulic Swivel Joints and Assemblies were first developed for high altitude aircraft service and are now widely used for both military and industrial installations. Numerous approved styles are available to meet J.I.C. and Mil-J-5513 Specifications. Leakproof; Pressure-safe! Low torque. No swelling or expansion under pressure. Sizes, ⅛" up. Operating pressure ratings to 3,000 psi. or higher; temperatures to −85° F., or lower. *Ask for information and recommendations.*

***Only* BARCO SWIVEL JOINTS *provide* Side Flexibility!**





Many Approved Designs for Military, Aircraft, and Industrial Use

BARCO
MANUFACTURING CO.
1827B WINNEMAC AVENUE
CHICAGO 40, ILLINOIS
IN CANADA: The Holden Co., Ltd.

The Only Truly Complete Line of Flexible Ball, Swivel, Swing and Revolving Joints

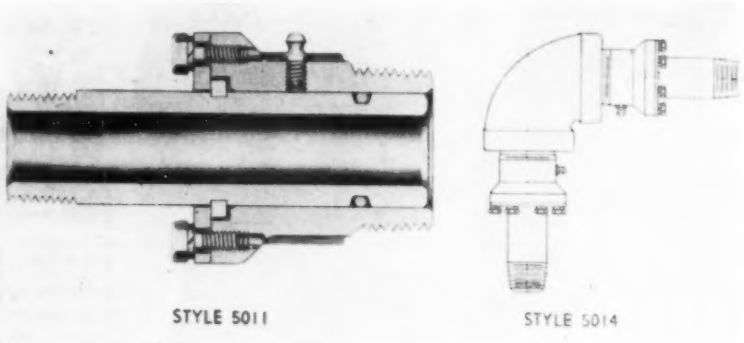
FREE ENTERPRISE—THE CORNERSTONE OF AMERICAN PROSPERITY

Swing Joints for Gasoline and Oil

To a line of swing joints have been added three new styles that are available in sizes from ⅜ in. to 12 in. depending on the model. The new joints are particularly applicable to gasoline and oil tank car or truck loading and unloading lines. Also, many overhead loading lines and hose reels which require joints that will support piping and move in one plane only.

The particular advantage of the new design is said to be its simplicity in allowing for a 360 deg rotation around the axis of the joint with a long bearing surface to support the weight of normal piping. When used in pairs, connected by 90 deg ell, they provide for up-and-down and side-to-side action. Easy arrangement for counter-balancing of supported piping is also possible.

Sizes available range from ⅜ in. to 3 in. for threaded connections and from 4 in. to 12 in. with flanged connections. A total of 60 different models are available. Sealing is by means of an "O" ring confined in a recess in the sleeve of the joint. Special "O" rings are provided for handling air gasoline, water, gas, chemicals, fuel oil and other liquids without softening, swelling, or deterioration at any pressure from 0 to 100 psi, or to as high as 500 psi in the smaller sizes. This material is also suitable for temperatures from —40 to 225 F. In all of the larger sizes, standard alemite fittings are used for lubrication of the joints. Parts are accessible for inspection and maintenance. Joints also available in stainless steel.



STYLE 5011 STYLE 5014

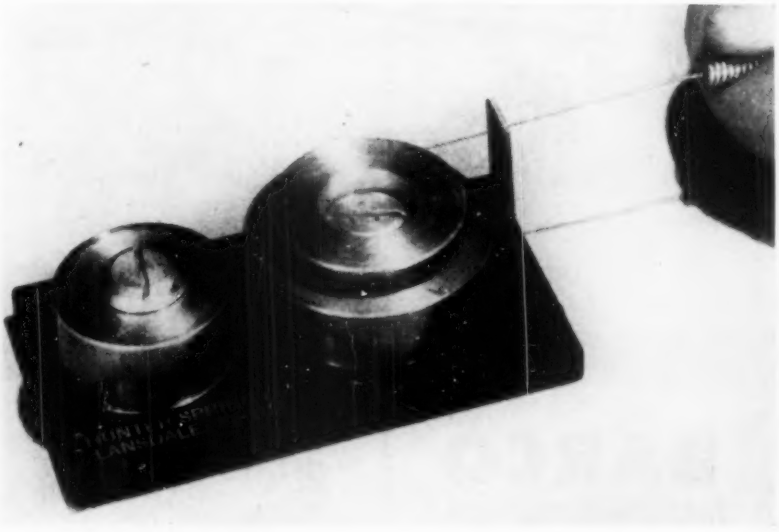
The Barco Mfg. Co., 1801 N. Winnemac Ave., Chicago 40, Ill.

Neg'ator Model Aids in Mechanisms Design

As an aid in the development of mechanisms based on neg'ator, a long deflection constant force spring element, a working model of the B-motor form of the neg'ator is now available made of a long strip of stainless steel, 0.005 in. thick and ½ in. wide. The zero-gradient neg'ator B-motor, mounted on a 2 x 3½ in. black bakelite base, exerts a constant torque of 0.75 in.-pound as the flexible steel output cable is drawn to an extension of about 4 ft.

The cable, stored on a 1 in. drum integral with the output bushing, is equipped with a looped terminal attachment to permit either manual or mechanical extension. From zero to full cable extension, a torque of 1 in.-pound is developed through 14 revolutions of the output bushing.

Neg'ator Div., Hunter Spring Co., 1 Spring Ave., Lansdale, Pa.



DRAFTING BOARDS measuring 42 in. x 72 in. are available on an all steel table that has a tilting range of from 0 to 50 degrees. Also adjustable for heights from 33 in. to 47 in., it is equipped with a leveling device and an adjustable foot rest. It has a large pencil tray and a leg base area of 25½ in. x 42 inches. Emrick, Inc., 1724 Clinton Ave., Kalamazoo, Mich.

CHEMICAL TRAYS, molded of high-strength chemical resistant plastic, resist acids, salts, mild alkalies, and organic solvents. The Dynakon Corp., 5509 Hough Ave., Cleveland, Ohio.

CONTINUED ON PAGE 224

LASTS TWICE AS LONG ...STILL GOING STRONG

QUAKER CONVEYOR BELTING

LASTED LONGER THAN ANY OF SIX OTHERS

A "belt-killing" drive on a well-known trench digging machine was wearing out conveyor belts in a matter of weeks or months. Then a Quaker "Pre-Tested" Conveyor Belt was installed. Result . . . belt lasted almost twice as long as any of the six different belts used . . . still going strong . . . in fine shape.

Performance records like this and thousands of others are making more and more design engineers specify Quaker Industrial Rubber Products as original equipment.

Quaker sales engineers can assist you in producing a new rubber product . . . or applying an existing one to meet your requirements from Quaker's complete line of belting, hose, packings and moulded goods. For "replacements" Quaker Products are available through leading distributors from coast-to-coast. Write for the *new* Quaker catalog for the latest data on industrial rubber products.

QUAKER RUBBER CORPORATION

DIVISION OF H. K. PORTER COMPANY, INC.

PHILADELPHIA 24, PENNA. BRANCHES IN PRINCIPAL CITIES

Small Float Valve Has Large Capacity

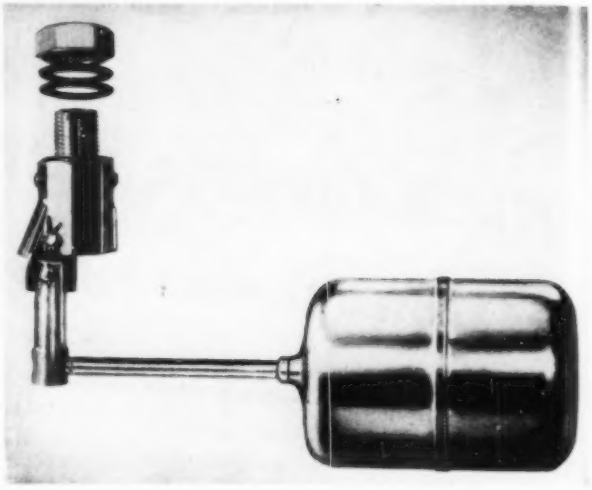
A new float operated valve, known as the no. 18 series, provides a large capacity for a valve of its small size. Three variations of the valve are available in this series. The no. 18, the 118, and the 518, which offer a variety of operating conditions.

The no. 18 consists of the valve mechanism and float. The no. 118, shown in the illustration, is a variation designed to offer protection against back-siphonage; it has the float mounted at right angles to the valve so that the valve proper is always far above the water level. The no. 518 includes the float and valve in a die-cast chamber, with a well-fitting cover, and is designed for external application such as on humidifiers.

The valve mechanism itself consists of only a few parts. Except for the neoprene valve seat, all parts are of copper or brass. The valve opens to full capacity with a small float drop, and closes against supply pressures up to 100 lb. The entire assembly is held together by a single brass pin, so it can be disassembled for inspection or cleaning.

The no. 18 series float valve can be used on humidifiers of warm air furnaces; on evaporative coolers in air conditioning equipment; on wet and dry bulb hygrometers; on ice cube freezers. It is also used to add water to radiators of stationary engines; on coffee urns and beverage dispensers.

The capacity of the no. 18 valve ranges up to almost 1500 gallons per hour, depending on supply pressure. For



mounting the valve, the water supply connection has a $\frac{5}{8}$ in.-18 machine thread with matching nuts and washers. For actual water supply line, either $\frac{1}{8}$ in. pipe or $\frac{1}{4}$ in. O. D. tubing, this same connection has a $\frac{1}{8}$ in. pipe tap.

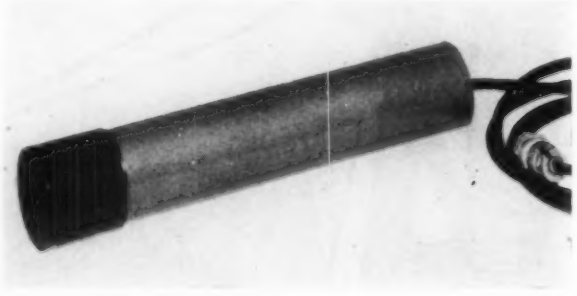
McDonnell & Miller, Inc., 3500 N. Spaulding Ave., Chicago 18, Ill.

Probe Has Interchangeable Detecting Heads

A new lightweight radiation probe, for detecting and measuring alpha, beta, gamma, and neutron radiations, has been designed for use in hospitals, and industrial and university laboratories where work with radioactive materials is being conducted. It will have application in monitoring contamination of clothing, personnel, laboratory equipment, and facilities.

The scintillation counter, includes a phosphor, photomultiplier tube, and a two-stage amplifier with low-impedence output. Light flashes, produced when nuclear particles strike the phosphor, are converted into electrical pulses by the photomultiplier. This allows radiation detection and measurement under even the most difficult circumstances. Alpha particles, for example, can be counted in the presence of high beta-gamma backgrounds.

The phosphors for detecting alpha, beta, gamma, and neutron radiations are incorporated into specially designed caps placed on the end of the probe. These detecting heads can be quickly interchanged and the various phosphors in the caps are easily replaced should the need arise.



The neutron cap alone, adapted to measure beams of thermal neutrons, is expected to have wide application in general health physics work.

The complete detector is $2\frac{3}{8}$ in. in dia, 15 in. long, and weighs approximately 10 pounds.

General Electric Co., 1 River Rd., Schenectady, N. Y.

AN ALL MAGNETIC REGULATOR has no vacuum tubes, has an all magnetic amplifier type circuit, and maintains a power supply output at 18,000 v d-c. This is for load current variations from 0 to 100 ma, and line voltage variations from 105 to 135 v a-c. Regulation accuracy is 1 percent. May be modified for power supplies of any output rating. Time delay about 0.1 seconds. General Magnetics, Inc., 135 Bloomfield Ave., Bloomfield, N. J.

THE CON-TORQ LOCKNUT, made with a flange and tempered ribbed barrel, gives concentrated action when applied to a bolt or screw. It is not affected by vibration, moisture, or heat or cold. E. A. Bessom Corp., Salem, Mass.

CONTINUED ON PAGE 226

FREE. Send for illustrated 20-page mainspring guide to better product design and performance . . .

Sandsteel Spring Division—Sandvik Steel, Inc.
145 Hudson Street, New York 13, N. Y.

Gentlemen: Kindly send, without obligation, a copy of "Sandsteel Springs for Dual Power."

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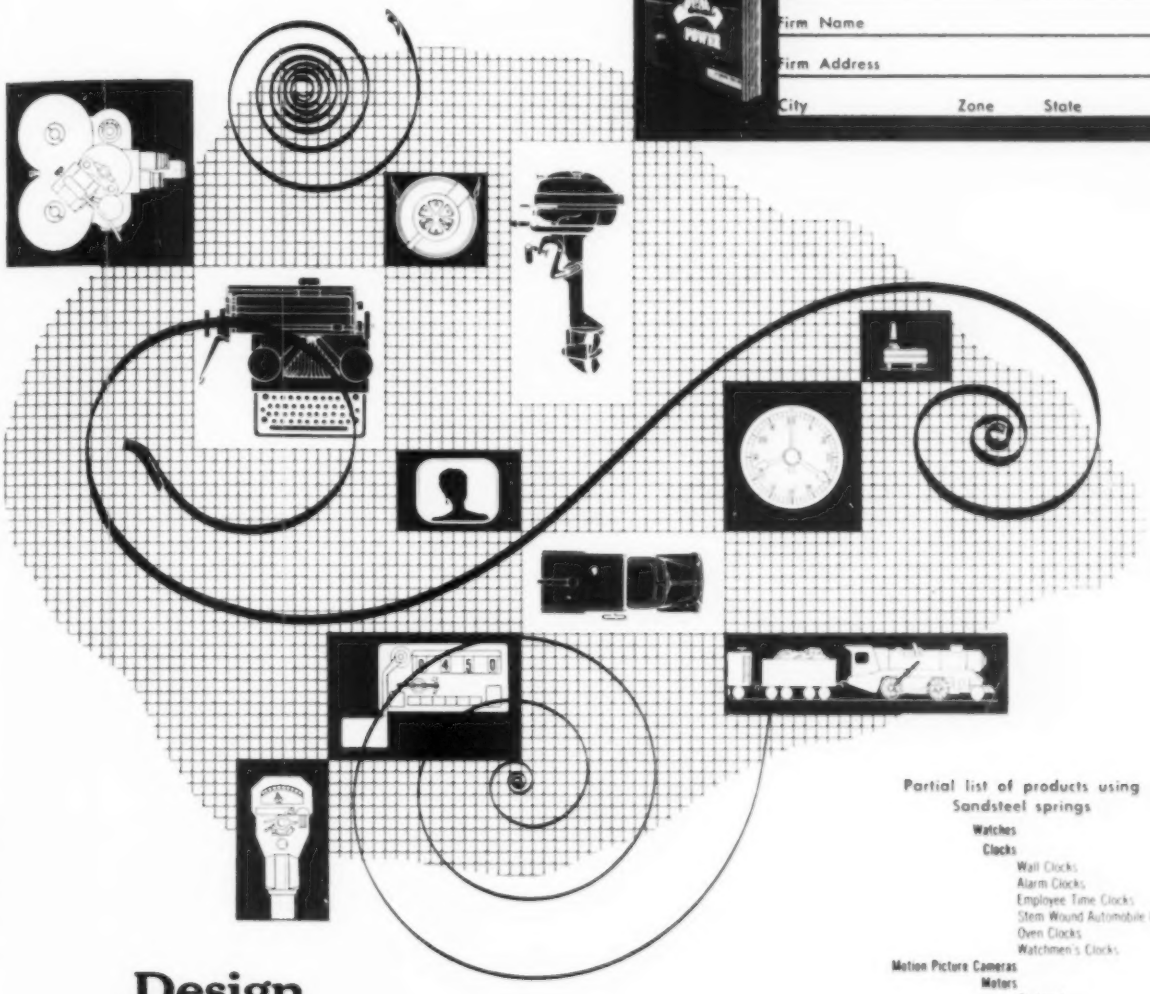


Design DUAL POWER into your product

DO YOU HAVE A PRODUCT THAT REQUIRES A FLAT SPRING? For superior design and performance of that product, inquire about Sandsteel CROSSCURVED Mainsprings. The crosscurving allows use of longer, thinner springs, giving more flexibility of design and a far more even delivery of energy. Take advantage of a quarter century of Sandsteel mainspring know-how, and consult us regarding your spring requirements. Write for informative brochure . . . without obligation.

Partial list of products using Sandsteel springs

- **Watches**
- **Clocks**
  - Wall Clocks
  - Alarm Clocks
  - Employee Time Clocks
  - Stem Wound Automobile Clocks
  - Oven Clocks
  - Watchmen's Clocks
- **Motion Picture Cameras**
- **Motors**
  - Outboard
  - Portable Saw
  - Power Lawn Mowers
- **Office Machines**
  - Calculators
  - Computers
  - Comptometers
  - Typewriters
- **Timing Devices**
  - Parking Meters
  - Switches for Washing Machines
  - Electric Time Switches
- **Instruments**
  - Tachometers
  - Altimeters
  - Gauges
  - Electric Meters
- **Recording Devices**
- **Earphones**
- **Eyeloupes**
- **Television Aerials**
- **Vending Machines**
- **Reels (return mechanism)**
- **Toys**

SANDSTEEL SPRING DIVISION—SANDVIK STEEL, INC.

General Offices and Main Plant: 145 Hudson Street, New York 13, New York

Two Or Three-Way Electrically Controlled Valves

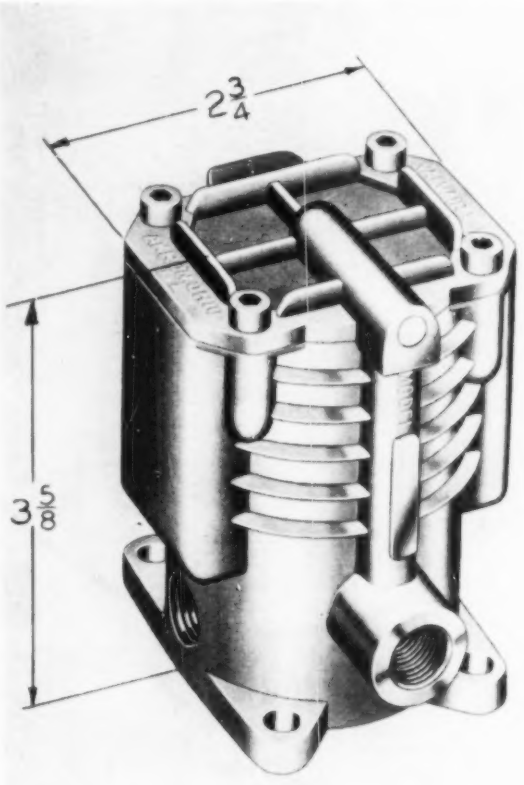
Recommended for use as a pilot of the cylinder or diaphragm operated valves, this electrically operated valve is being offered in a 2- or 3-way model, in 110, 220, and 440 v, 60 cyc, either normally open or normally closed.

The body and cover are a high tensile zinc alloy die casting, and the seats, plunger, and spring are made from stainless steel. The hycar seats in both ends of the plunger are oil resistant, and the coils are completely sealed from the air or fluid being controlled. The air or fluid passing through the center of the valve dissipates the heat of the coil, keeping it cool, and allowing operations up to 400 cyc per minute.

The life of the valve is said to be over 10 million cycles. The only moving parts are the spring and the plunger. The only wearing part is the hycar seat, and when a new seat is molded into the plunger, the valve is ready for another 10 million cycles. A valve with a standard coil is recommended to handle air or oil only. A special shielded coil is used in valves handling water and will be available at a later date.

Valves with $\frac{1}{8}$ in. orifice are recommended for pressures up to 125 psi; valves with $\frac{3}{16}$ in. orifice are recommended for pressures to 60 psi. All valves have a $\frac{1}{4}$ in. pipe tap. The $\frac{1}{4}$ in., $\frac{3}{8}$ in., and $\frac{1}{2}$ in. cylinder valve can be operated up to 300 cyc per min, and the $\frac{3}{4}$ in. and 1 in. cylinder valve can be operated up to 150 cyc per min with this valve. The restrictors must be removed from the top of the cylinder operated valve to obtain these speeds. Inrush current consumption is 41 watts, holding current is 27 watts. It is recommended that for maximum service the valve be mounted in a vertical position to prevent excessive wear on the plunger.

Valvair Corp., 961 Beardsley Ave., Akron 11, Ohio

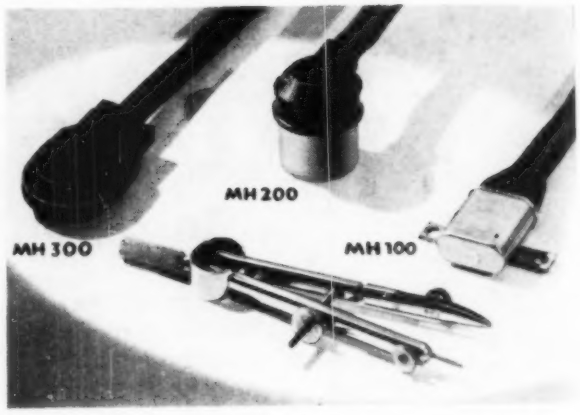


Bimetal Disk Thermostat Is Completely Sealed

A new quick make and break bimetal disk thermostat for defrost control and cycle termination, and for other application in which moisture beads are a problem, is designed to meet all requirements of the Underwriters Laboratory.

Featuring an electrically independent bimetal thermal element which eliminates artificial cycling or jitters, the new thermostats are available in two basic styles. Type MH200 is a hermetically sealed unit enclosed in a round metal can with neoprene molded over the terminals and leads. Type MH100 is enclosed in a CR-7 crystal can; type MH300 is covered by a molded neoprene enclosure. This construction completely protects the terminals from moisture or liquids; silicone rubber can be used for special high temperature applications. The silver contacts are protected from contaminants by the hermetic seal.

All type MH thermostats are preset at the factory and cannot be adjusted thereafter. Operating on a-c of 40 cycles and up, the units are rated at 15 amps at 115 v and 10 amps at 230 volts. General applications for the type CH 100 include use in low wattage circuits where thermal control is necessary, as in electronic and communication equipment, and in control apparatus and appliances where moisture beads are a problem. All the CH 100 type thermostats are permanently precalibrated for any range from a maximum of 400 F to as low as —60 Centigrade.



Stevens Mfg. Co., Inc., 69 S. Walnut St., Mansfield, Ohio

CONTINUED ON PAGE 228

You can replace seamless tubing or pipe with our

ROLLED STEEL SPACER TUBES OR BUSHINGS

and save money in machining material labor

PROMPT DELIVERY

FEDERAL-MOGUL

FEDERAL Mogul

Since 1899

Our six plants produce sleeve bearings in all designs and sizes; cast bronze bushings; rolled split-type bushings; bi-metallic rolled bushings; washers; spacer tubes; precision bronze parts and bronze bars.

FEDERAL-MOGUL CORPORATION · 11043 SHOEMAKER · DETROIT 13, MICHIGAN

V-Belt Drive Unit for Instrument Calibration

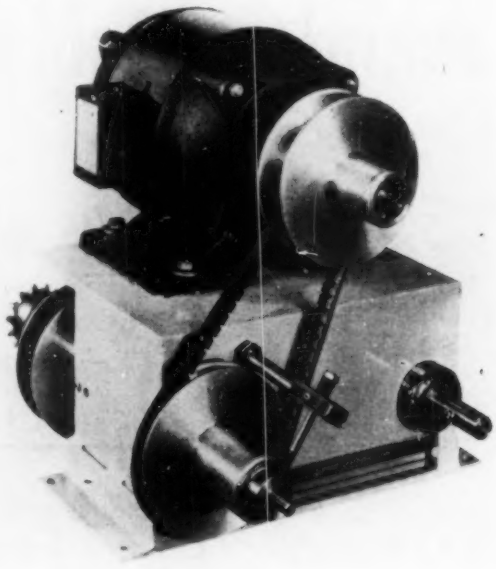
A special purpose compound V-belt drive unit has been found to be suitable for the calibration of jet controllers, tachometers, and other instruments.

Capacities ranging from the light tachometer drives of ½ hp or less up to 10 hp are now available with larger drives for loads of 20 hp and higher now being developed. Ratios up to 50:1 with speed ranges from 150 to 7500 rpm are produced by compounding successive pairs of wide range combination sheaves.

Prelubricated sealed ball bearings and precision built variable pitch sheaves equipped with sintered bronze bushings are incorporated in the design. This construction is said to assure uninterrupted performance without the necessary regular servicing. The balanced stretchless steel cable V-belts are furnished either in regular or static proof construction for hazardous locations. A single, free-operating balanced control with zero back lash for direct or remote locations changes the pitch diameter of all four sheaves simultaneously.

Accuracy of regulation with no hunting and almost no drifting are said to hold speed variations to less than ¼ of 1 percent for any speed throughout the entire range. This is important when using electronic tachometers in conjunction with the calibration of instruments, controls and pumps.

Speed Selector Inc., 118 Noble Court, Cleveland 13, Ohio



High Rate Counting and Totalizing Unit

High speed counters, used in conjunction with conventional equipment, and instruments, now permit high rate counting and totalizing at near ultrasonic rates. Possible applications of these counters are investigation of phenomena involving functions of time, radiant energy, sound, light, acceleration and velocity, stress analysis. Other uses are in: hydraulics, pneumatics, nuclear physics, and aerodynamics. Determining production and flow rates in the processing and fabricating industries are also possible.

Designed for lightness, portability and ruggedness, these units weighing 10 oz apiece, have an overall dimension of 1½ in. x 5 in. x 5½ inches. Model TU-9 automatically records impulses up to 30,000 per second, while model TU-100 will record at rates as high as 100,000 cycles per second. Both units are equipped with octal base plugs for individual or series mounting in conjunction with other equipment or circuits. By cascading a series of units, direct readings of large proportions may be read on the internally illuminated panels. Power supply is 200-400 v, d-c at 12 milliamps, with an input-output pulse of 100 v, negative.

Stratex Instrument, 1861 Hillhurst Ave., Los Angeles 27, Calif.

A MINIATURE HERMETICALLY SEALED RELAY features an 8-terminal hermetically sealed header 0.600 in. O.D. and a new design balanced armature relay sealed in a ⅞ in. x ⅞ in. drawn aluminum can. The entire unit is so constructed that it may be panel mounted from either the top or bottom side. The unit can be furnished either with a dry air fill or vacuum pumped and filled with dry nitrogen. Hermaseal Co., Inc., Elkhardt, Ind.

A SELF-LOCKING ANCHOR NUT of high carbon annealed spring steel grips the bolt without using an auxiliary device. Its hardness makes cross-threading almost impossible. Kaynar Mfg. Co., 820 E. 16th St., Los Angeles, Calif.

CONTINUED ON PAGE 230

WATER can't cramp your product's performance

NURSING BOTTLE CAP
Pyramid Rubber Co.

ENGINE DEHYDRATOR
Clark Metal Products Co.

COMMERCIAL HUMIDIFIER
Daffin Mfg. Co.

TOILET TANK FLOATS
Plano Molding Co.

. . . when it's custom molded of DUREZ phenolics

● Water resistance should seldom be overlooked in materials selection, and often it is a controlling factor.

This characteristic is outstanding in Durez phenolics and, as these examples suggest, it can serve you in many ways. Frequent contact with hot liquid causes no deterioration in the sanitary screw-on nursing bottle cap and nipple holder. Toilet tank balls of Durez float for years. Engine dehydrator plugs are unaffected by any climatic conditions and have the torque strength needed for a tight screw fit. Constant exposure to water vapor neither swells, shrinks nor warps the humidifier parts of molded Durez, nor mars their lustrous finish.

In millions of pieces of electrical and electronic equipment the low water absorption of Durez is equally important . . . it safeguards the excellent electrical characteristics of the material.

Your custom molder will help you get maximum profit from the electrical, chemical, and mechanical properties available in more than 300 Durez molding compounds. Why not see him now, before future plans become 'set'? Our field staff is at your service for details and technical assistance.

Our monthly "Durez Plastics News" will keep you informed on industry's uses of Durez. Write, on office letterhead, to Durez Plastics & Chemicals, Inc., 2001 Walck Road, North Tonawanda, N. Y.

PHENOLIC PLASTICS THAT FIT THE JOB

Tester Has Range From 2 Grams to 5,000 Lb

Outstanding among the features of a new precision electronic testing instrument, is its wide full scale range, extending from 2 grams to 5,000 lb. In addition, a selection of jaw speeds is provided, ranging from 0.02 to 20 in. per minute. The combination of a system for changing the load sensitivity and push button switching for operating the moving crosshead, are said to offer fast routine measurements as well as complex testing techniques.

The electronic load weighing system is based on the electric strain gage principal to detect variations of load in the specimen under test. This instrument has a high speed of response and almost zero motion of the upper jaw. The motion of the lower jaw is controlled by a positional servo system assuring a constant rate of elongation in either direction, and providing almost instant starting, stopping or reversing.

Recent additions to the tester have been compressional accessories. An auxiliary and easily removable crosshead, as shown in the illustration, is attached to the frame below the moving crosshead. Compression type load cells have a rigidly attached load sensitive table. The sample is compressed between this table and the moving crosshead. The same control for operating the motion of the crosshead in tensile measurements, is possible for compression testing. Load deformation, cyclic, and relaxation data, can be obtained with high speed response. By the use of jigs and fixtures, torsion and flexural measurements may be carried out.

The full scale range of compression tests available, with three interchangeable load cells, extends from 20 grams to 5,000 lb. An integrator has been developed which, when applied to the tensile tester, the area under the load deformation curve, which is equivalent to the energy either absorbed or returned by the test sample, is immediately available from counter readings.

Instron Engineering Corp., 2 Hancock St., Quincy 71, Mass.

Step Gage Measures Thickness of Thin Films

Called a step gage, this new instrument for accurately measuring the thickness of thin films by means of color comparisons, consists of a specially prepared glass plate enclosed in a plastic case. A film of barium stearate is deposited on the glass in a series of monomolecular layers, each layer having a thickness of 0.1 microinch. The successive layers are deposited in such a way as to build a series of steps made up of ten layers. Each step is one microinch thicker than the preceding one.

When the step gage is illuminated by white light, each step reflects a color that is determined by its thickness. The steps, therefore, are seen as a series of colored stripes on the glass plate. To determine the thickness of an unknown film, it is compared with the colors on the gage to find the step which most nearly matches the color of the unknown film.

The new device may be used to measure vapor pressures and temper colors on metals, and is adaptable for measurement of transparent conductive coatings on glass. The range of the step gage is from 2 to 16 microinches.

General Electric Co., 1 River Rd., Schenectady 5, N. Y.

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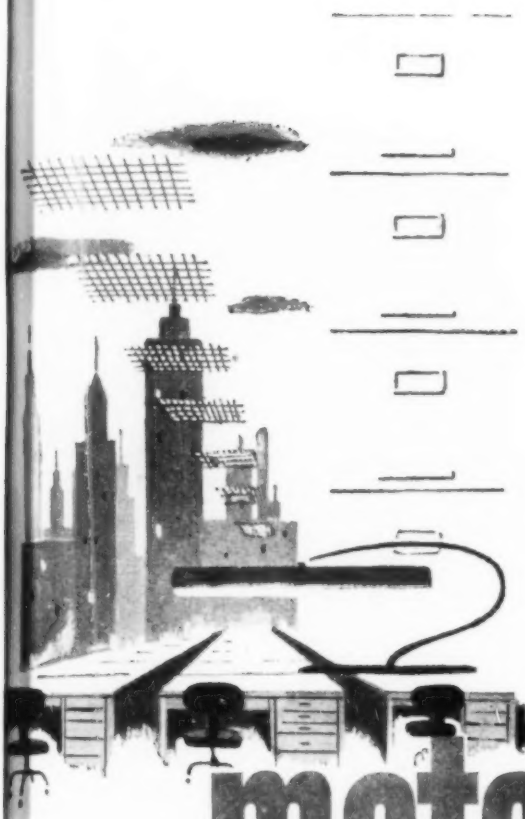
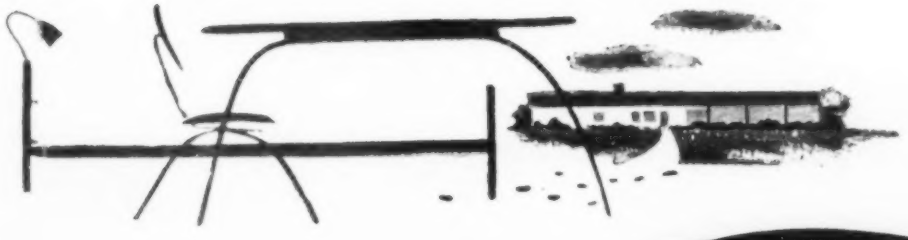
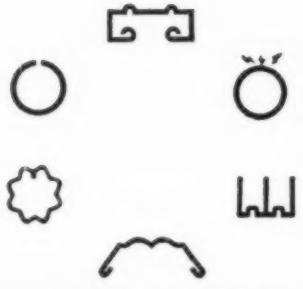


Functional beauty . . . lighter weight . . .
greater strength . . . are only a few of the reasons
why Van Huffel metal tubing and shapes
make the "sky the limit" for designers
of metal furniture. From office desks to day beds . . .
from high chairs to hall trees . . . the list
keeps on growing. As one manufacturer aptly put it,
"You make in metal what we put on paper."
Van Huffel is versatile.

Van Huffel
cold-formed metal tubing and shapes
simplify the production
of

metal furniture





VAN HUFFEL

TUBE CORPORATION • WARREN, OHIO

WELDED, LOCK SEAM, OPEN SEAM, BUTTED TUBING, SHAPES AND MOULDINGS

Vibration Mount Protects Voltage Regulators

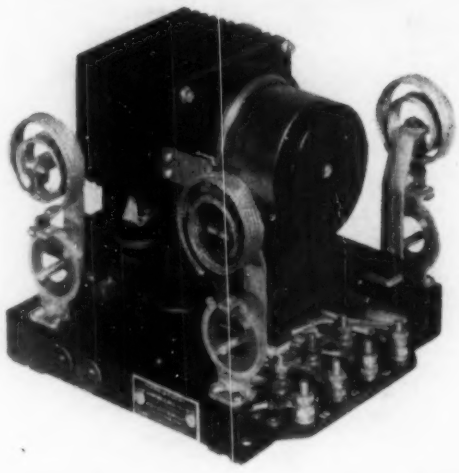
A new center-of-gravity type vibration isolation mount has been developed to protect aircraft voltage regulators from the effects of shock and vibration. It is reported to offer good vibration resistance in all kinds of mounting and has constant characteristics over a wide temperature range. The mount is designed to meet the requirements of Army and Navy specifications 17R21 and ANB30.

The mount is capable of withstanding a shock or sustained acceleration of 10 Gs, and will absorb vibration deflections of 0.06-in. (total travel) when subjected to simple harmonic motion at frequencies of 10 to 55 cps and amplitudes corresponding to 10 Gs from 60 to 200 cycles. It also meets a 25 hr salt-spray test.

Four phosphor-bronze laminated spiral springs with copper braid sleeves are located at the corners of a movable base so that the inner ends of the springs are equi-distant and in the same plane as the center of gravity of the device to be protected. Brackets riveted to the outer and inner ends of the springs secure them to rigid and movable bases.

The device so protected may be mounted in any plane and subjected to shock and vibration in any direction. The springs will deflect substantially the same amount in any direction when loaded. Unbalanced movements of the device are eliminated when it is subjected to shock or vibration.

Four silicone-rubber grommets inserted in the spring supports act as stops under shock conditions. Their performance is also effective between wide temperature limits



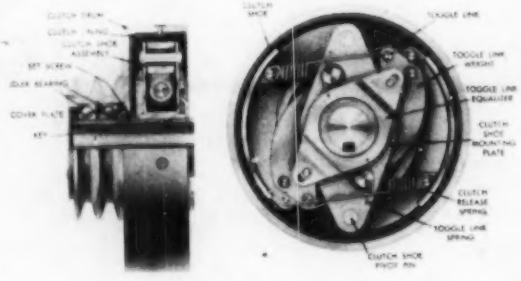
because of the characteristic stability of silicone rubber over a wide temperature range.

A thumb-type locking clamp is used so that the plug-in voltage regulator may be easily removed. Test jacks and an equalizer potentiometer are mounted on the rigid base.

General Electric Co., 1 River Rd., Schenectady, N. Y.

Automatic Clutch Disengages At Low Speeds

A new automatic clutch, featuring wide differential in engagement and disengagement speeds, is designed for operation on any 7 to 15 hp engine with $1\frac{1}{8}$, $1\frac{7}{16}$, or $1\frac{1}{2}$ in. standard shaft. It has a normal engagement speed of 1,000 to 1,200 rpm, but disengages at as low as 800 rpm. The wide differential of this automatic clutch is made possible by a linkage connecting heel and toe of the two opposing shoes. This toggle lock is centrifugally actuated and equalized on both pickup and release of the load. All models in this Tog-o-loc series have hub bores mating with standard engine shafts, without necessity for any extension, grinding, boring or slotting. They are available in two types —with standard size pulleys with single and double grooves, or with plain hubs onto which special service pulleys may be mounted.



Salsbury Corp., 1161 E. Florence Ave., Los Angeles 1, Calif.

FLAG TYPE SOLDERLESS TERMINALS are now equipped with body insulation. The terminal may be installed easily on standard wires in ranges from No. 22 to 10. Originally designed for intricate case wiring systems, the terminals may be used in aircraft, industrial, automotive, electronic, or where space is at a minimum. Aircraft-Marine Products, Inc., 2100 Paxton St., Harrisburg, Pa.

NEW EXTRUDED TENITE PLASTIC SHEETING reinforced with wire is said to have good resistance to outdoor exposure. The transparent plastic is lightweight, non-corrodible, and high in impact strength. The plastic used is cellulose acetate butyrate tenite. G Felsenthal & Sons, Inc., 4100 W. Grand Ave., Chicago 51, Ill.

CONTINUED ON PAGE 234

HOW TO HELP BRITAIN ...and Ourselves

The purpose of this editorial is to help Winston Churchill obtain the aid Britain needs

(1) to weather her present financial crisis, and

(2) to avoid a chronic recurrence of such crises.

This is not a philanthropic purpose.

Britain is our staunchest ally in the free world's continuing fight for survival. She cannot perform her role effectively if she is broke, or if she careens from one financial crisis to another.

Then, too, a nation such as ours—committed to private enterprise as a way of economic life—has a special interest in helping Winston Churchill to help Britain. His administration is relatively friendly toward private enterprise. Should he fail, he would be replaced promptly by a Socialist government more hostile than ever. And that would weaken the standing of private enterprise in the free world.

Cause of the Crisis

It is the drive of the Western World under our leadership to rearm against Russian aggression that has precipitated Britain's financial crisis. It set off a scramble for raw materials from which armaments could be made, and for many other materials that might be short in the event of war. So the prices of the things that Britain must import—mostly raw materials—have been boosted more than the prices of things she can export—mostly finished products. That leaves Britain short of funds to pay for essential imports. This difficulty increases as the necessity becomes more urgent to divert industrial effort from production for export to production for security.

The Basic Trouble

Although Britain's immediate crisis was touched off by the rearmament drive of the Western World, her basic affliction is one from which she has suffered since the end of World War II. Stated in its simplest terms, Britain does not produce enough goods to pay her own way as one of the family of free nations.

For years this deficiency in home production was made up by income from shipping and overseas investment. But Britain had to sell a large part of her foreign investments to finance her heroic part in World War II. So her income from that source has been greatly reduced. And, in spite of an increase of about a third above prewar in her own production of goods and—thanks to a continued "austerity" program—a much larger increase in her exports, Britain still is not paying her own way.

Two Ways to Solvency

Britain has two ways to restore her solvency. One is to cut down on what is consumed—the belt-tightening process. The other is to step up British production.

To surmount the present crisis, Mr. Churchill has asked for some cutting down. He probably must ask for more.

Except as a stop-gap expedient, however, more cutting down of Britain's consumption is clearly a dangerous course. That would further depress a British standard of living which, not more than half as high as ours, already is too low. Politically such a course would grease the skids for Winston Churchill's administration, even now governing by a wafer-thin parliamentary margin. Also, as *The* (London) *Economist* remarks, the "lazy expedient of cutting trade" would result in "hurting other people and forcing them to take similar action"—by cutting the market for their products.

The Only Cure

The best and, in fact, the only way to help cure Britain's economic ills is to help Britain produce more. Here the technical possibilities are encouraging. On the average, the British industrial worker produces only about 40 percent as much a year as the American worker. That is a British estimate, made by Sir Ewart Smith.

Wider use of better industrial methods and modern tools and an infusion of the competitive incentive into British industry — to replace the cartel and other restrictive practices — would go a long way to narrow this wide gap in worker productivity. This is the consensus of experts on both sides of the Atlantic.

Since 1948 the Anglo-American Council on Productivity has done much to encourage output per man-hour in Britain and to foster this doctrine with both labor and management. But much yet remains to be done.

In the United States it is increasingly suggested that before we give Britain any more economic aid we should insist that everything possible be done to exploit the technical possibilities of increased production. This emphasis on production is needed. But if we Americans were to impose upon the hard-pressed British people conditions that could be construed as an affront to a friendly and sovereign nation, we might well put into the hands of a masterful rabble-rouser such as Aneurin Bevan, the anti-American leader of the Labor Party's left wing, a campaign issue on which to maneuver himself into the Prime Ministership.

Churchill Can Insist

But Winston Churchill is not so handicapped as we should be in imposing prerequisites of further aid. As Britain's own, most honored leader he will raise no touchy questions as to Anglo-American relations if he insists that Britain have firm plans to cure her economic ills, plans sharply focussed on ways and means of increasing Britain's industrial efficiency.

By presenting a convincing plan to cure Britain's recurring crises through greater production, Mr. Churchill will greatly facilitate the process of getting the aid his country must have. He will also remove an increasingly dangerous element of dissension in Anglo-American relations — the feeling of many Americans that more aid to Britain is more money down the drain. The way to counter that feeling is to come up with a prescription for an economic cure, not a request for another economic poultice.

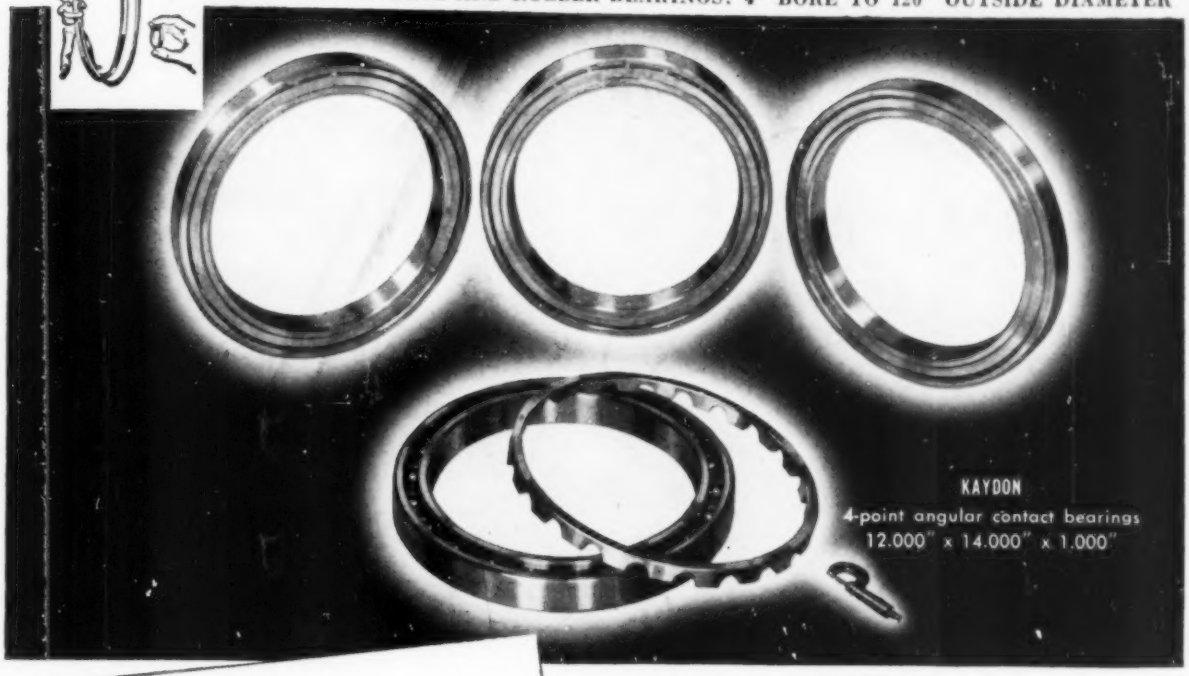
Technically, such a program is entirely feasible. It will perhaps be the supreme test of Winston Churchill's statesmanship to make it politically feasible as well.

In the interest of Britain, of the United States and of the whole free world, we wish him all success.

McGraw-Hill Publishing Company, Inc.

Contact KAYDON of Muskegon

FOR ALL TYPES OF BALL AND ROLLER BEARINGS: 4" BORE TO 120" OUTSIDE DIAMETER



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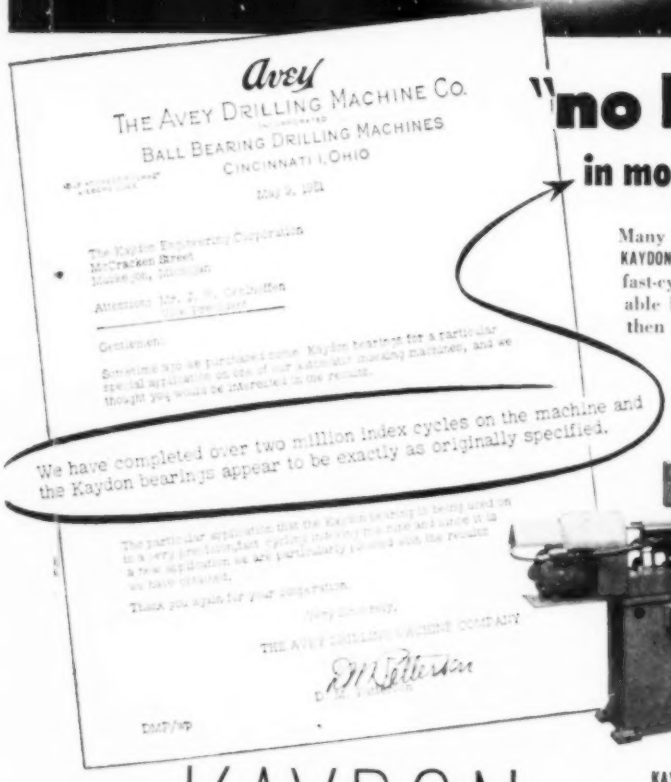
4-point angular contact bearings
12.000" x 14.000" x 1.000"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THE AVEY DRILLING MACHINE CO.
BALL BEARING DRILLING MACHINES
CINCINNATI I, OHIO

We have completed over two million index cycles on the machine and the Kaydon bearings appear to be exactly as originally specified.

"no bearing wear"

in more than 2 million indexing cycles

Many are the big responsibilities successfully shouldered by KAYDON bearings in heavy-duty machinery. For instance, Avey fast-cycling high precision Indexing Machines demand dependable bearings to stand the strain of drilling 3 precision holes, then indexing the part 60 degrees and drilling 3 more holes. After more than 2-million indexing cycles, without perceptible bearing-wear, Avey is "particularly pleased" with KAYDON Bearings . . . adaptable to many types of precision machinery . . . maybe *yours*, too! Call KAYDON.

Avey 16" Automatic Indexing Machine, with Aveydraulic drill units, torquematic control and 6-station automatic indexing table.

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PRECISION BALL AND ROLLER BEARINGS

It's always SPRING TIME at NO. 2 JOHN ST.

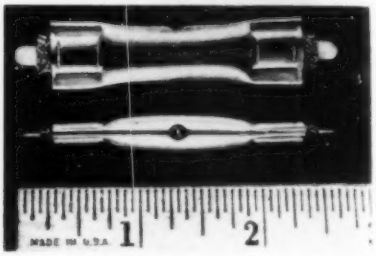
In fact, we at American-Fort Pitt Spring have been making coil springs—all kinds, hot or cold wound—spring, summer, fall and winter, for more than sixty years. Over the years our engineers have worked on almost every conceivable type of spring problem. In many instances their recommendations have helped cut production costs and improve product performance. The springs we furnish are delivered precisely as specified and in conformity with highest standards. When you need springs, the No. 1 place to think of is No. 2 John Street.

AMERICAN-FORT PITT SPRING DIVISION
H. K. Porter Company, Inc.
No. 2 John Street, McKees Rocks, Pa. (Pittsburgh District)

AMERICAN-FORT PITT SPRINGS

Sensitive Dead-Case Thermostat

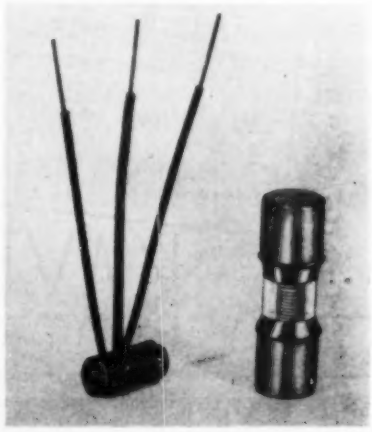
The new insulated case of the Dual Mite Thermostat features high capacity, greater sensitivity and simpler installation. The dual action thermostat, rated at 500 w capacity, has an operating range at temperatures from 32 to 400 F, and according to the manufacturer it has high thermal sensitivity and can be calibrated to close thermal limits. A dielectric rating of over 1,300 v is claimed. It is especially designed for difficult appliance applications where pre-set, fixed calibration, and long thermostat life are required. The aluminum case measures 2-$\frac{5}{8}$ in. long by $\frac{5}{8}$ in. wide. The unit can be supplied with choice of terminals or leads to meet exactly the application need.



Mechanical Industries Production Co., 218 Ash St., Akron, Ohio

Subminiature Selenium Rectifiers For Military Applications

The Minisel line of subminiature selenium rectifiers, consists of tiny selenium rectifiers in ratings up to 20 ma d-c output, 25,000 v a-c input per single stack, and features a variety of constructions for military and commercial applications. Special constructions



allow for hermetic sealing and fungus proofing.

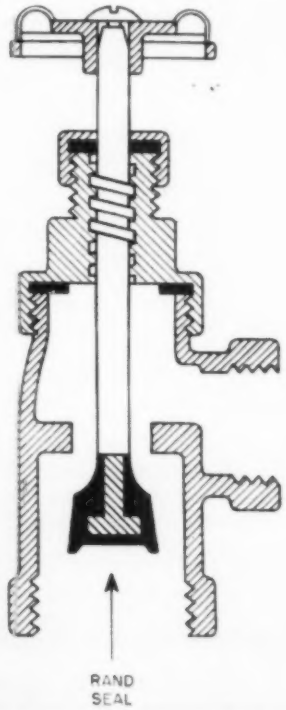
These rectifiers are constructed of matched ¼ in. dia round selenium rectifier cells encased in bakelite, glass or metal housings. The company claims a strict quality control production to eliminate variance in characteristics within the unit, and from unit to unit.

The rectifiers are built in all common and a large variety of special shapes, including a line of standard instrument and spark suppressor rectifiers.

Electronic Devices, Inc., 429 12th St., Brooklyn 15, N. Y.

Leak-Proof Valve

Using a new type of valve design called the rand seal, has resulted in a valve that is said by its manufacturers to be leak-proof, long wearing, and easier operating. The operation is based on working with, rather than against, the fluid flow. The cone-shaped seal is closed in the same direction as the movement of the liquid, allowing high or low pressures to seal the valve. This is said to eliminate leak-inducing permanent deformation found in previous designs based on the compression of a resilient member against a non-resilient seat.



RAND SEAL

The cup-shaped conical washer of

The ABC of MST

Michigan Electric Resistance WELDED STEEL TUBING

A ALWAYS MAKES POSSIBLE
B BETTER PRODUCTS
C AT LOWER COST

A Quality Product

ROUND
⅜" to 4" O. D. 9 to 22 gauge

SQUARE-RECTANGULAR
½" to 2" 20 gauge, 1" to 2¾", 14, 16, 18 gauge

Carbon 1010 to 1025

Michigan Tubing has uniform strength, weight, ductility, I. D. and O. D., wall thickness, machinability, and weldability. It can be flanged, expanded, tapered, swaged, beaded, upset, flattened, forged, spun closed, fluted, and rolled. Available in a wide range of sizes, shapes and wall thicknesses, prefabricated by Michigan or formed and machined in your own plant.

Consult us for engineering and technical help in the selection of tubing best suited to your needs.

We Did It Before..

We rolled up our sleeves before and the whole world was amazed at the miracle of American production. Now we're at it again and Michigan is proud to be doing its share in this great defense effort.

Michigan electric resistance welded steel tubing found its way into numerous products for the armed forces during World War II, such as automobiles, trucks, incendiary bombs, and airplanes. Another use was invasion line tubing. Design simplification and adaptability, qualities making for economical and faster production, were among the reasons why so many manufacturers turned to Michigan tubing.

As we "do it again" during the present defense emergency, consider how Michigan tubing can be applied to your product. We'll appreciate the opportunity of discussing its use, whether for defense or consumer items.

Michigan ELECTRIC RESISTANCE WELDED STEEL TUBING STEEL TUBE PRODUCTS CO.
THE OLDEST NAME IN ELECTRIC

More Than 30 Years in the Business
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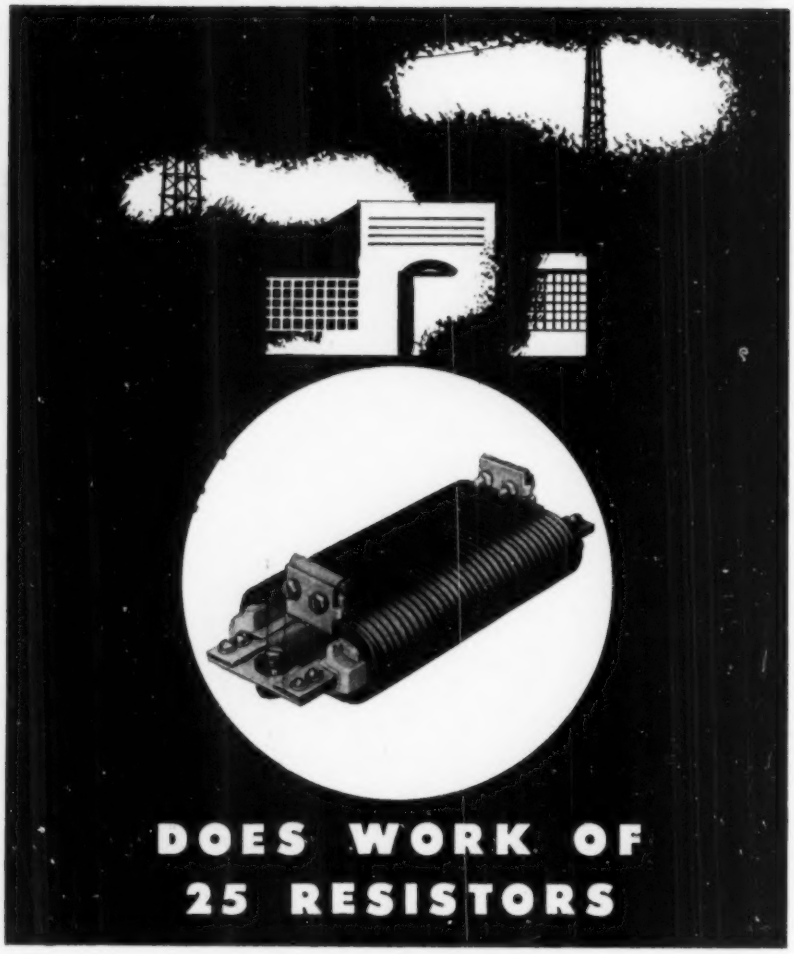


**saves work—and cost—
of hooking them up**

It used to take 25 conventional resistors, 11¾ x 1⅛ in., spaced on 2½ in. centers, to keep the power company happy.

Ward Leonard worked out the problem with a *single* Edgeohm resistor, 19 in. long—saving all that space, weight, mounting and wiring.

Here's the application: a 40-kw radio transmitter, operating from a 50 kva transformer, made by a large transmitter manufacturer. Problem: limiting inrush current to avoid a severe voltage drop (objected to by the power company) and a strain on the line contactor.

This single Edgeohm unit is rated for continuous duty at 2200 watts, and when used for a 15-second interval, will dissipate 6400 watts!

Another example of Ward Leonard "Result Engineering", providing the desired result at a saving! WARD LEONARD ELECTRIC CO., 63 South Street, Mount Vernon, N. Y. Offices in principal cities of U. S. and Canada.

**WARD LEONARD
ELECTRIC COMPANY**

Result-Engineered Controls Since 1892

RESISTORS • RHEOSTATS • RELAYS • CONTROL DEVICES

the rand seal incorporates an imbedded metal plug which eliminates bending and warping and makes the seal leak-proof. If contaminants in the fluid such as sand or grit, are not pushed ahead of one sealing line contact, the conical shape of the seal provides establishment of a new line of contact without damage to the bore. The rubber member of the seal is compounded to withstand oil, grease, steam, water, and most industrial chemicals.

Rodic Chemical And Rubber Corp., Allen Ave., New Brunswick, N. J.

Lightweight General Purpose Centrifugal Pumps

A new line of general purpose centrifugal pumps, known as type SCC, are light in weight, easy to handle, install and mount, and are well suited for any small pumping application such as small cooling towers, domestic water supply, or hot water systems. They may also be adapted to booster and process pumping, or stock pump packing gland water supply.

The SCC pumps are of close coupled type. For leak-proof operation and to eliminate frequent adjusting or gland repacking, they are equipped with mechanical seals. Motors are of the standard open drip type. Standard mounting is vertical, but with the addition of motor feet, the pumps can be adapted for horizontal mounting.

By removing four bolts, the entire pump can be lifted out for maintenance. Impellers, wearing rings, and mechanical seals are easily replaced. Standard pumps are bronze fitted with casing and motor stand of close-grained, cast iron. Impellers and wearing rings are of hard bronze. The impellers are dynamically balanced and hand fitted.

Two sizes are available: 2 in. suction x 1¼ in. discharge and 1½ in. x ¾ inch. Both operate at 3450 rpm. Capacities range to 100 gpm at heads to 120 feet.

Economy Pumps, Inc., Hamilton, Ohio

Metal-Plating On Plastics

A new method of plating metal on items of bakelite and vinylite plastics makes possible lightweight, corrosion-resistant products with hard, high-polish metal surfaces. Metal-plated bakelite and vinylite plastics are said to be more resilient, lighter to carry, and are more highly resistant to heat, abrasion and weathering than solid metal. The

mass production method of electroplating is performed in barrels made of acid-resistant laminated phenolic plastic. Hardware, jewelry, bottle closures, molds for slush molding doll parts and shielding for electronic circuits are a few of the items molded of bakelite and vinylite plastics. These may be electroplated with gold, silver, copper, and other metals in a variety of 12 colors. Abrasives roughen the smooth plastic surface so that a thin bond coat of silver, applied by immersion or spraying, will adhere. When dry, the bond coat is tested for electrical conductivity which makes it possible to electroplate objects by tumbling inside a perforated barrel revolving in a copper salt solution. A base coat of copper plate is followed by a thin layer of the desired metal finish.

Plastiplate Co., Inc., South River, N. J.

Moisture Content Easily Determined

A moisture testing instrument, model PD 1, has been specifically designed for testing wood flour, wood shavings, wood chips, sawdust and similar by-products. The principle of high frequency power absorption gives the model PD 1 accurate testing to zero per cent moisture. The instrument has a penetration of 3 in., is portable and simple to operate. Moisture content is determined by pressure of the gun electrode against a sample of the material, preferably placed in a small container such as a wide-necked glass jar. The instrument operates with a press of the thumb and one reading only is required to determine moisture content.

Moisture Register Co., 1510 W. Chestnut St., Alhambra, Calif.

Reinforced Plastic Sheet

Dynakon G1A a medium high strength glass fiber reinforced plastic sheet has been designed for a sheet intermediate in strength between A3A machining and electrical grade sheet and E1B high-strength sheet. G1A also has good properties for stressed applications in the electrical chemical and appliance field, and is suitable for use in making luggage and trunks. Tensile strength is 19,000 psi, compressive 24,000 psi, impact is 15 ft-lb. G1A is resistant to acids, salts and mild alkalies as well as to organic solvents. Water absorption is 0.30 percent.

Among the electrical properties are: dielectric strength, 325 v/mil; arc resistance 120 sec; and power factor, 4.7.

. . . A-C or D-C . . . multi-pole construction . . . many more uses

Now you can get fast, positive, consistent operation on a *wide range* of load and control circuits . . . from the finest design of solenoid contactor on the market.

This new Size O a-c contactor brings Ward Leonard's line of solenoid contactors into the 15 ampere range. And it comes with as many as 5 poles. Double-break silver contacts may be interchanged to form normally-open or normally-closed contacts as desired.

Operating coils are interchangeable with Size 1 contactor coils. Available also with d-c "power plants".

Write for Bulletin 4458. WARD LEONARD ELECTRIC CO., 63 South Street, Mount Vernon, N.Y. Offices in principal cities of U. S. and Canada.

WARD LEONARD ELECTRIC COMPANY

Result-Engineered Controls Since 1892

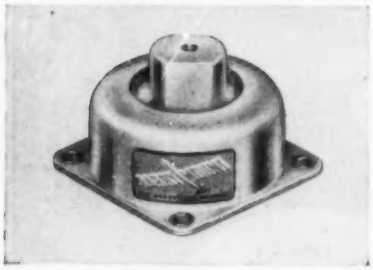
RESISTORS • RHEOSTAT • RELAY • CONTROL DEVICES

SHOCK and VIBRATION NEWS

BARRYMOUNTS FOR ASSURED CONTROL OF SHOCK AND VIBRATION

NEW ALL-METL BARRYMOUNTS

for Unusual Airborne Applications



These new Barrymounts provide the aircraft and electronic engineer with a vibration isolator designed to meet the unusual temperature and environmental conditions encountered in high-altitude, high-speed flight. Employing no organic materials, these mountings are not subject to temperature influences that may affect the performance of other mountings.

ALL-METL Barrymounts offer a wide load range with uniform performance. They have a natural frequency of about 7½ cycles per second, with low horizontal stiffness for maximum isolation of horizontal vibration. Transmissibility at resonance is only 4½. There is no snubber contact nor resonance carry-over when ALL-METL Barrymounts are vibrated at government-specified amplitudes.

These mountings are designed especially for unusual military conditions. They meet the vibration requirement of JAN-C-172A, MIL-E-5272 (USAF), and MIL-T-5422 (BuAer). For details of sizes, ranges, and construction of unit mounts and bases using ALL-METL Barrymounts, see catalog 509.

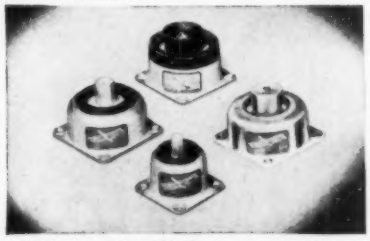
FREE CATALOGS

- 502 – Air-damped Barrymounts for aircraft service; also mounting bases and instrument mountings.
- 509 — ALL-METL Barrymounts and mounting bases for unusual airborne applications.
- 504 — Shock mounts and vibration isolators for marine, mobile, and industrial uses.
- 607 — How to cut maintenance costs by using Barrymounts with punch presses.

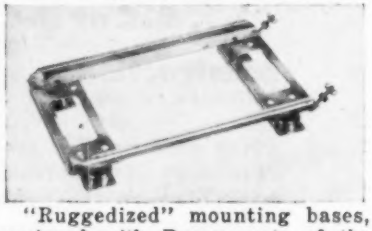
"RUGGEDIZED" BARRYMOUNTS AND MOUNTING BASES

Now Available to Meet Shock Requirements of AN-E-19

Barry vibration isolators and mounting bases are now available in "ruggedized" construction, to withstand the severe shocks of arrested landings in aircraft carrier service and of crash landings. These units are tested to meet the shock-test requirements of Specification AN-E-19, for the equipment sizes listed in JAN-C-172A.



"Ruggedized" Barrymounts are available in both the air-damped type and the ALL-METL type. Air-damped Type 770R covers load ranges between ¼ lb. and 9 lbs. Air-damped Type 780R covers load ranges between 4 lbs. and 35 lbs. ALL-METL Type 6600R covers load ranges between 4 lbs. and 35 lbs. Type M-112R covers ranges between 2 and 10 lbs.



"Ruggedized" mounting bases, equipped with Barrymounts of the above types, are available in standard JAN sizes (JAN-C-172A) and in special sizes to meet customers' requirements. A conspicuous advantage of these "ruggedized" Barry bases is the gain in strength of the base framework itself — beyond JAN requirements — achieved with very little increase in weight for loads up to 60 lbs. by design modification of standard JAN bases. For greater loads, the "ruggedized" Barry bases are of stainless steel instead of aluminum. Write for data sheet.

THE BARRY CORP.

730 PLEASANT ST., WATERTOWN 72, MASSACHUSETTS

SALES REPRESENTATIVES IN

New York Boston Philadelphia Washington Cleveland Dayton Detroit

Chicago Minneapolis St. Louis Seattle Los Angeles Dallas Toronto Atlanta

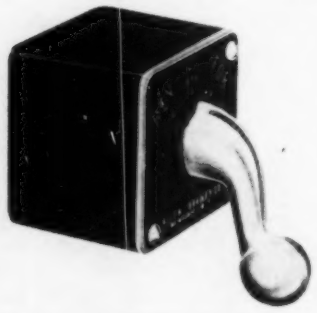
Dielectric constant is 4.40 and specific gravity is 1.49. Sheet size available at this time is 18 x 28 in. in thicknesses of $\frac{1}{16}$, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{3}{8}$ and $\frac{1}{2}$ inches.

Dynakon Corp., 5509 Hough Ave., Cleveland 3, Ohio

Reversing Drum Switch For Small Motors

This new, compact reversing drum switch, suitable for a variety of arrangements in small shops, is the equivalent of three-pole double throw switch. It is a small, simply designed switch for machines and equipment requiring an across the line starting and reversing switch for a-c and d-c motors rated at two hp or less.

The housing is of bakelite, and contains eight fixed contacts, a moving contact assembly, handlecover plate



assembly, and mounting screws. Contacts are cadmium silver alloys, reducing maintenance. Flexibility in mounting is provided. Typical applications include drilling machines, lathes, milling machines, and laboratory equipment.

The switch, called the model 350 style A reversing drum switch, is said, by the manufacturer, to be well suited for applications where space and cost are important factors.

Allen-Bradley Co., Milwaukee, Wis.

Foam Core Material Is Strong

Corfoam, a new liquid phenolic resin foam core material, has a compressive strength up to 500 psi. When mixed cold, it will foam to a hard consistency without applied heat at room temperature. It is of honeycomb appearance with tiny globular, nonconnecting cells, and has a density of approximately 14 lb per cubic foot.

Corfoam can be foamed in large masses without loss of cell control or undue shrinkage. It will not soften under heat and tests show it has excel-

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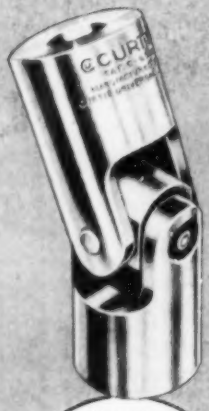

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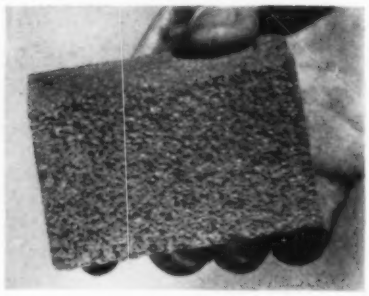

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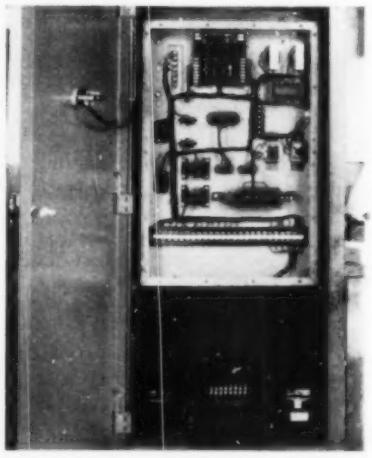

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January 14-17

PLANT MAINTENANCE CONFERENCE & SHOW—Convention Hall, Philadelphia, Pa.

January 14-18

SOCIETY OF AUTOMOTIVE ENGINEERS—Annual Meeting, Headquarters at Book Cadillac Hotel, Detroit, Mich.

January 16-18

SOCIETY OF PLASTICS ENGINEERS, INC.—Eighth Annual National Technical Conference, Edgewater Beach Hotel, Chicago, Ill.

January 28-February 1

INSTITUTE OF AERONAUTICAL SCIENCES—20th Annual Meeting, Astor Hotel, N. Y.

January 31-February 1

AMERICAN SOCIETY FOR METALS—Midwinter Technical Meeting, William Penn Hotel, Pittsburgh, Pa.

March 3-6

INSTITUTE OF RADIO ENGINEERS—Waldorf-Astoria Hotel and Grand Central Palace, New York.

March 3-7

ASTM SPRING MEETING AND SYMPOSIUM ON TESTING METAL POWDERS AND METAL PRODUCTS—Hotel Statler, Cleveland, Ohio.

March 11-14

SOCIETY OF THE PLASTICS INDUSTRY—Fifth National Plastics Exposition, Convention Hall, Philadelphia, Pa.

March 17-19

FLUID MECHANICS—Second Midwestern Conference, Ohio State University, Columbus, Ohio.

March 17-21.

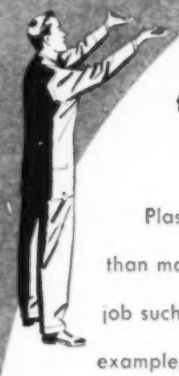
AMERICAN SOCIETY OF TOOL ENGINEERS—1952 Industrial Exposition, International Amphitheater, Chicago, Ill.

March 18-19

STEEL FOUNDERS SOCIETY OF AMERICA—Edgewater Beach Hotel, Chicago, Ill.

April 1-4

AMERICAN MANAGEMENT ASSOCIATION PACKAGING SHOW—Atlantic City, N. J.



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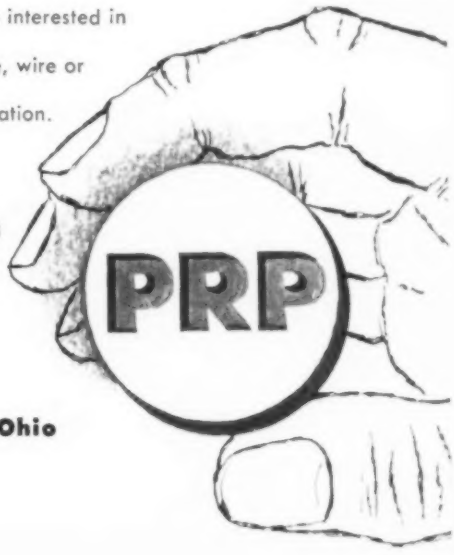

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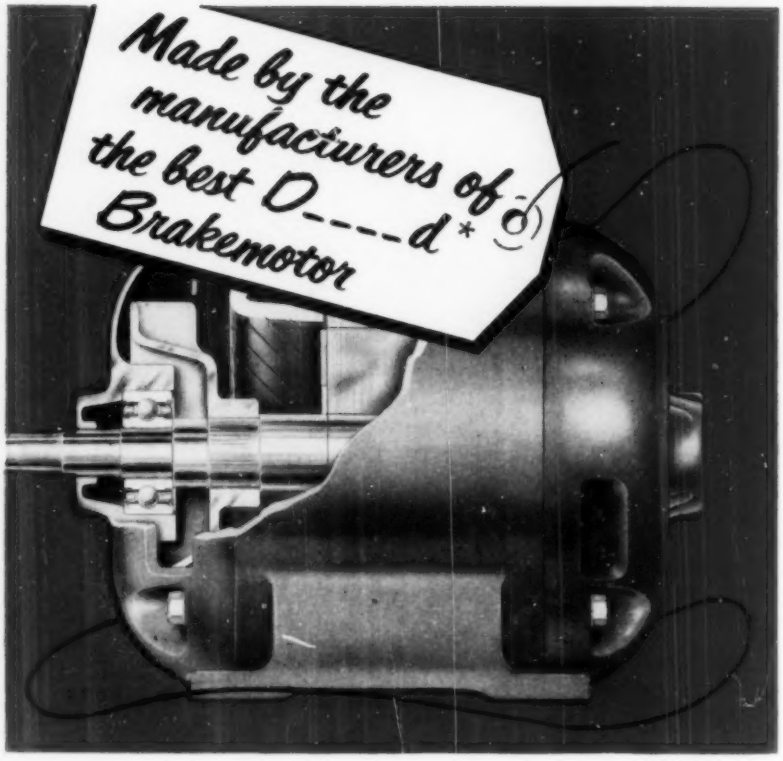

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ENGINEERING ABSTRACTS

Application and Function of Gear Oil Additives

Abstracted from Lubrication, April 1951. Published by The Texas Company.

A GEAR OIL ADDITIVE may be defined as a chemical compound which either imparts new properties to the lubricating mixture or enhances the properties which the oil already has.

In the formulation of gear lubricants the additives generally used fall into fairly well defined groups depending on the type of gear and the conditions of operation involved.

Type 1—No additive

Straight mineral oils give satisfactory service on many types of gears under normal operating conditions—light load and low or high speed.

Type 2—Non-corrosive type, sulphurized fat additive.

A gear lubricant containing a sulphurized fat such as lard oil is specified for spur, bevel or spiral bevel gears for "run-in" or "break-in" purposes. After the initial fill a straight mineral oil is specified for normal operating conditions.

With sulphurized fats, it is intended that sulphur be available to prevent welding by forming iron sulfide at the metal to metal peak contacts. The sulphur must be sufficiently stable to prevent staining of copper and brass, hence the "non-corrosive" designation.

Type 3—Non-corrosive type, lead soap, sulphur, phosphorous, polar agent (optional)

This class of gear lubricants is intended for many types of gears operating under conditions of high load and/or speed. The additives must be chosen to be active chemically under these conditions. Welding at high temperature is prevented by the formation of an easily sheared film of iron and lead sulfide and also by the formation of a low melting point phosphorous alloy. In this manner, welding is prevented over a range of operating conditions. Oftentimes, the mere prevention of welding is not sufficient for satisfactory lubrication and a polar compound must be used to reduce friction and afford acceptable operating temperatures.

Type 4—Corrosive type, lead soap, active sulphur

The adoption of the hypoid gear by the automotive industry for high

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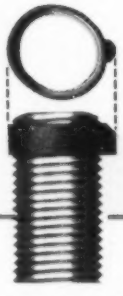

Look at the picture just above. This shows a cross-section of a Security Locknut. The insert, indicated removed and shown above the nut, is of high quality, heat treated, alloy spring steel and becomes a permanent part of the nut.

The insert acts purely as a locking device. The load is borne by the nut, not the insert. The insert is elliptical in shape and this design causes the retainer to grip the bolt with the terrific tension that only spring steel of great strength could exert and prevent the nut from turning. *Simple—dependable—positive!*

THERE is no other fastener or lock nut like this! No other fastener or lock nut will do what a Security Locknut will do. If you were to design a lock nut it would have the features of Security. It stays put where you wrench it even in face of vibration that would wreck the bolt.

It does not require *bolt tension* but stays in place on a loose bolt. It can be readjusted, removed and replaced, not 15 times, not 100 times, but *any number of times* without materially reducing the torque or locking power or injuring the bolt. It is a complete unit—no extra parts to slow up installation—nothing to line up—nothing to shear—no threads to cut—just a simple nut, made perfectly to specifications for standard bolts.

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Authoritative tests have proved conclusively the gripping power of Security Locknuts. We'd like to have you see the results of these tests. If you have a vibration or fastening problem, Security Locknuts are the dependable, positive solution. Made in 3/8 to 2 3/4 in. bolt sizes, both U.S. and SAE threads. Ask to see the Security Locknut tests.

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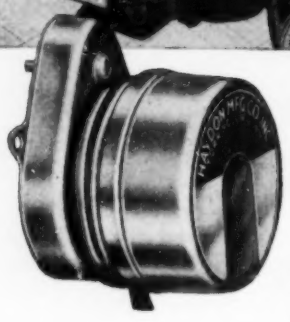

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speed low torque condition required a gear lubricant that would prevent welding where gear tooth pressure is high, coupled with a pronounced wiping effect. To do this it has been found necessary to choose additives to prevent welding but—the temperature and rate of formation of the easily sheared film must be regulated and controlled. This can be done by using a lead soap and active sulphur. This class of gear lubricant causes a high wear under high torque—low speed conditions. The active sulphur is bound in a rather loose chemical manner and controlled to be available at the required temperature and in the proper amount. When present at this high level of activity copper will stain. This type of lubricant is particularly effective when shock type loading is a factor.

Type 5—Non-corrosive type, chlorine, sulphur, phosphorous

With the widespread application of the hypoid gear in passenger car and truck service—high speed/low torque and low speed/high torque conditions—it was necessary to modify the lubricant described in (4) to accommodate the more severe conditions of tooth pressure, wiping action and temperature and to prevent wear.

In the formulation of lubricants for this service, additives containing chlorine, sulphur and phosphorous are employed. The essential variation from (4) is that the formation of iron chloride which prevents welding is catalyzed or speeded up by severe operating conditions. The role of phosphorous is similar to that previously described.

Type 6—Non-corrosive type, lead soap, sulphur, chlorine, polar compound (optional)

This type of gear lubricant is similar to that in (5) since the lubrication of hypoid gears is the primary purpose. From an additive standpoint the principal change is the inclusion of a lead soap and the omission of phosphorous. There is evidence that it will handle more severe operating conditions than the conventional Universal Gear Lubricant.

This difference can be shown in controlled road testing procedures. It has been found that a lubricant which will give satisfactory service in a severe road test involving a 1½ ton tractor-trailer unit (24,000 pounds gross) operated at 19 MPH average over mountainous terrain for 3000 plus miles will not necessarily pass 2-105B requirements. This statement is not made from the standpoint of criticism. Instead it is believed to support the theory that gear lubricant additives must be chosen on the basis of chem-

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ical activity and this property must be fitted to predetermined operating conditions to obtain best results.

Problems of Plating Powder Metal Parts

Abstracted from "Problems of Plating Powder Metal Parts" by J. D. Shaw, W. V. Knopp and C. L. Clark, Metal Finishing, November, 1951

THE PROBLEMS ENCOUNTERED in attempting to plate a metal powder part are numerous, and this discussion must therefore be somewhat limited. In the course of practical application of plating processes to powder metal parts other problems will arise which are not covered herein.

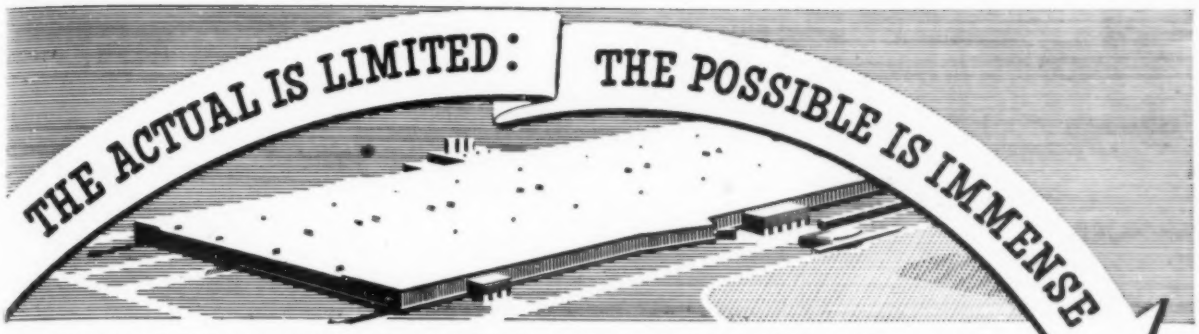
The types of powder metal parts can be broken down into three general classifications. These may be called for simplicity; (a) porous parts; (b) dense parts and (c) intermediate parts.

If porous parts were to be plated (which fortunately is seldom required) it would seem more feasible to plate the particles of powder, if possible, rather than to plate the finished object. Even under optimum circumstances, a considerable percentage of the voids would be covered during any plating operation, and this condition would result in an impairment of the actual functions of such parts.

Since it is an advantage to have as much open network within such compacts as is feasible, if it is necessary for these products to be used in a corrosive or erosive atmosphere or liquid, experience indicates that they should be made of corrosion or erosion-resisting powder materials, rather than depend on a plated surface for these properties.

The job of plating completely dense structures is no different from that of plating a cast, wrought, forged or machined part. In other words, plating of a powder metal structure with a dense surface would be handled by the same technique as would the plating of any massive part.

Parts of intermediate porosity are the ones which are not intentionally porous, but which do have a certain degree of porosity as a result of the practical limitations placed on the processing (which means they may be anywhere from 85–95% of theoretical density) and because they must be made at a relatively low cost and from a relatively inexpensive material. In this category would fall the so-called powder metal machine parts, the parts which are being substituted on a straight cost basis for parts made by other processes. These machine parts not only have porosity within the com-



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By **Robert F. Christian,**
General Manager, J. D. Christian Engineers
San Francisco, California

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2. Shorter shop schedules are improving our own deliveries by eliminating the demand for core work formerly required on our original designs and which was not attractive to suppliers.

3. With welded construction, our products are more adaptable for use on special machines. For example, the relocating of mounting bolt holes is now easier.

4. Ninety per cent of the machining time formerly required has been eliminated.

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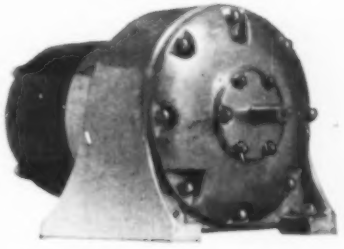

Fig. 1. Original Construction of gear motor housing. *Required 90% more machining.* Weighed 175% more than welded steel.

Fig. 2. Present Weldesign in Steel. *Costs 50% less.* Further saves shipping costs "prepaid" by manufacturers, using the product.

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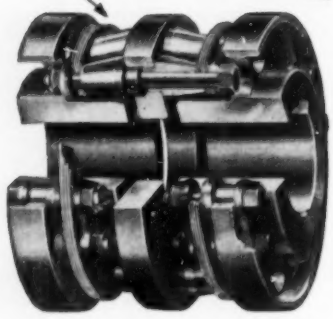

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pact, but they also have a certain amount of surface porosity.

In most cases, it is not practical from a cost standpoint to coin these parts in order to close over this surface porosity. A number of methods have been attempted for plating such parts, with most of these methods being based on closing the surface porosity by some means so that plating can be done over the surface without penetration of plating solution into the pores of the compact. The methods of closing the surface of a compact include those of physically working the surface, of coating it with some compound, and of heat treating the compact to fill up the surface voids and make the part amenable to conventional plating.

Since the largest category in metal powder parts is the intermediate one where there is unintentional porosity, parts of this type have received the greatest attenion in respect to plating. Articles have been written describing methods which are used in practice; (a) that of heat treatment of the surface, used for ferrous parts and (b) that of mechanically working the surface, for brass powder parts. Both methods have been used with some degree of success, although both are fairly new. These two methods are briefly described in the following paragraphs.

One process suggested of plating powder metal parts directed toward eliminating the "spotting out" condition normally encountered. The methods used involve heat treatments to remove residual plating salts. In his description, he states that the plating of porous metal parts involves a number of special problems among which are: (1) pressed and sintered parts have a velvety rather than a glossy finish, due to their irregular surface, and the surface porosity makes it difficult to obtain a uniform deposit of plating metal, (2) the difficulty of completely sealing the surface of such parts by plating them and (3) the danger of internal corrosion caused by entrapped liquids or salts from the electrolyte.

A proprietory method of plating powder metallurgy parts called "Etolizing", was developed to overcome these difficulties. Actually, three methods are possible; 1. the electroplating of a "green" unsintered compact, followed by washing, a neutralizing acid dip if required, and then sintering the compact in the conventional manner, 2. the short presintering of a "green" compact to increase its handling strength and clean its surface, followed by electroplating, washing and dipping if required, and finally subjecting the compact to the full sin-

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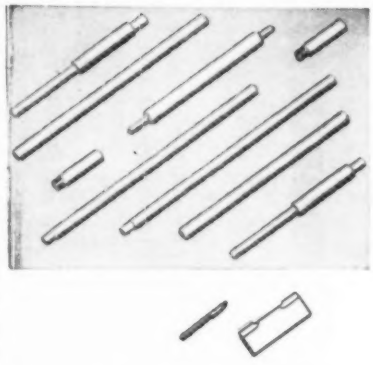

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tering operation, 3. the electroplating of a fully sintered part, and then a short heat treatment to volatilize residual salts from the pores. Essentially, it is claimed that method 1 can be used for high and heavy section parts and 3 is particularly adaptable for parts which are to be oil impregnated for self-lubrication.

SCOTT describes work conducted on plating at The Illinois Lock Co. The parts plated were brass lock parts which were given a chrome plate.

The porosity in the metal powder parts is reported as the main source of difficulty encountered. Reduction of the surface porosity by impregnation, re-coining and hand or mechanical burnishing were found to be impractical from a cost standpoint. The two types of trouble caused by porosity were eliminated by a set cycle and resulted in successful plating of the brass powder parts.

The low conductivity of the metal part was the most serious difficulty. With low conductivity it was difficult to obtain uniform distribution and adhesion of the nickel and chrome coatings. A base coating of copper plate was used.

The porosity also resulted in retained oil and acid in the pores which makes extremely thorough cleaning methods necessary. If not thoroughly cleaned, the plating will be attacked from underneath immediately and the plate will soon flake off.

Development work done at The Illinois Lock Co. eliminated these two difficulties by a cycle which included a base coat of copper and a variety of cleaning steps, all of which were carefully controlled.

A third article of considerable interest was that prepared by Graham, Pinkerton, Anderson and Reinhard. These co-workers studied the plating of powder metal parts at the New Jersey Zinc Co. by running a series of preliminary tests on the plating of 85–15 brass parts with nickel-chromium and copper-nickel chromium. The chief difficulties were "drag-out," i.e. contamination of plating baths by material retained in the pores of the compact, and "spotting-out," i.e. corrosive reaction between the electrolyte retained in pores and the plate. These difficulties were attacked, with varying degrees of success, by the following steps in various combinations:

A. Mechanical Working of the Surface
B. Elaborate Cleaning and Rinsing Operations
C. Copper Plating
D. Buffing of Copper Plate
E. Copper Cleaning

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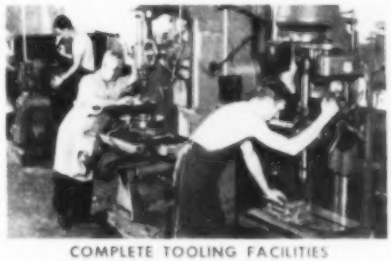
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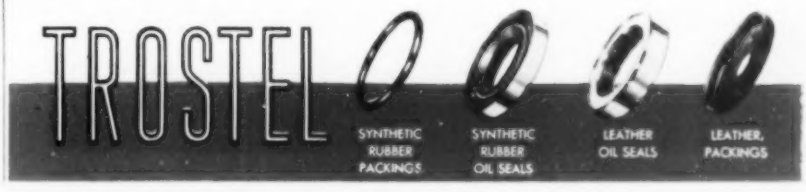

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F. Plating with Nickel or Nickel-Chromium

The test results, which were somewhat inconclusive, are summarized by Graham, et al. as follows:

1. The procedures described apply to 85–15 brass.
2. The actual plating area is much larger than was calculated because of voids and surface porosity, as was demonstrated when an attempt was made to plate to a predetermined thickness.
3. Variations in compacting pressure were not found to be important, although slightly denser compacts were more troublesome to process successfully, probably because of greater difficulty in cleaning and rinsing relatively smaller pores.
4. The following precautions were investigated in an attempt to prevent "drag-out" with consequent contamination of plating solutions:
   a. Prolonged cold water rinsing (not satisfactory).
   b. Alternate hot and cold water rinsing (better than (a).
   c. A weak neutralizing dip prior to hot and cold rinsing was most effective in reducing "drag-out" and also aided in preventing "spotting-out."

It was found that "drag-out" with standard untreated specimen may be ten times that with a similar piece treated to reduce surface porosity.

It was found necessary to use a good anodic alkali cleaning agent in the cycle if pores were to be cleaned effectively.

The following methods of closing surface porosity were investigated:

1. Impregnation—cost made it impractical.
2. Mechanical Working
   A. Hand brushing—effective
   B. Re-pressing
   C. Ball burnishing
   D. Polishing or buffing

It was found that (D) was most effective, followed by (C) and (B) in that order.

It would seem that a plating technique for porous powder metallurgy parts must be worked out for each individual case. The porosity of the powder metal part is the factor that creates the problem in the plating process. When the conventional plating techniques are used, two types of difficulties are encountered; a) the porous part is low in conductivity, which makes it difficult to obtain a uniform distribution of plating, and b) the retention of oil and acid in the pores results in "spotting-out".

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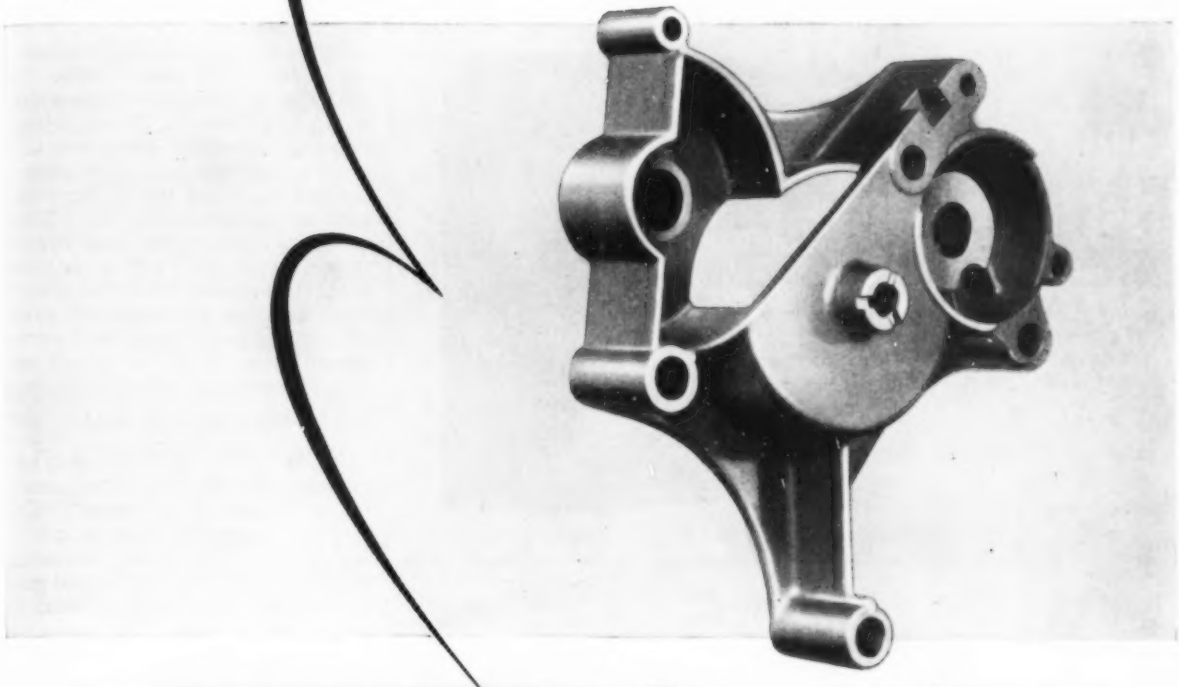

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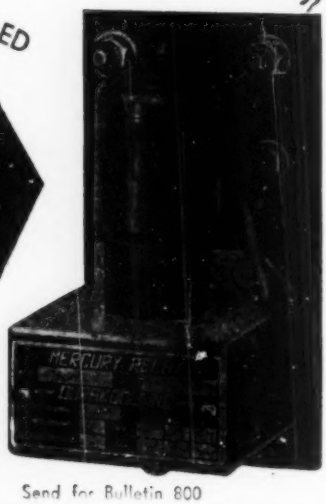

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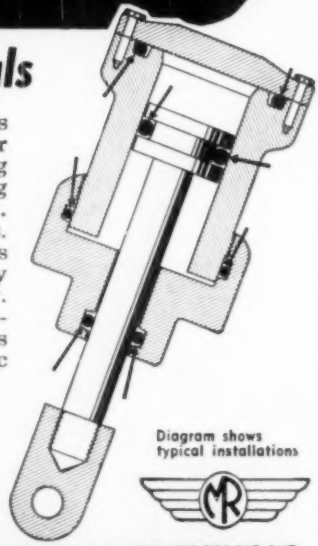

Diagram shows typical installations

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Sans, Souci

Ad Libbing By The Editor

Many years ago I heard a splendid talk. It was while I was a sophomore at college. Many of my learned acquaintances at that time vowed that it was wonderful. The talk was given by a Bishop of some city or another and I don't even know whether he was a Catholic Bishop, an Episcopolian Bishop or a Methodist Bishop. I have forgotten everything about that talk except one statement which the speaker repeated again and again. The statement was something like this: "This country is in great need of an aristocracy of brains and without such an aristocracy this nation will deteriorate." That statement was made in about 1910. Many people claim that the prophesied deterioration has already begun. In my opinion it has.

More Brains Indeed

It took quite a while for me to understand what the good Bishop meant by an "aristocracy of brains". The generally accepted meaning of an aristocracy is a ruling class. However, aristocracy also refers to groups of people who have outstanding qualities of some type or other. For example, according to Webster, aristocrats are: "Those who are superior to the rest of the community as in wealth, rank or intellect". The Bishop emphasized intellect.

There are many men who have brains but not all of them have intelligence. Undoubtedly the good bishop referred to an aristocracy of brains combined with intelligence. That would be the definition of outstanding men who are not only smart but use their exceptional brain power for constructive purposes.

It seems that today there are tremendously strong influences putting pressure upon men, especially those who should be of highest integrity, to accept lower moral standards, to give support to unwise movements or to espouse a certain cause of questionable character. Too many men, especially among those holding political office, have yielded. Often such demoralization can be traced to the desire of the individual for rank and power. Demoralization thrives best during periods of "prosperity," false though the prosperity be. As Goldsmith put it, "Ill fares the land to hastenings ills a prey, where wealth accumulates and men decay."

Rome is still the Eternal City but

Multiply Pressure

without increasing horsepower

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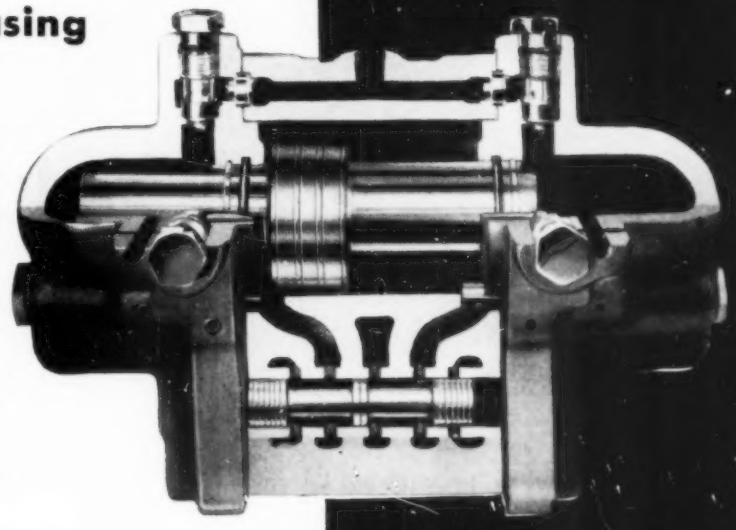
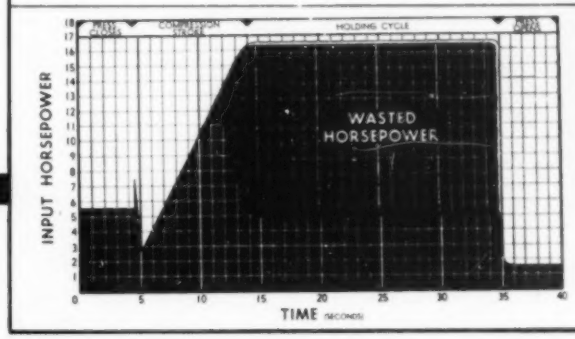
This means lower first cost, less horsepower consumption, reduced cylinder sizes — a more compact over-all design. Pressure and volume delivered can be controlled by one of the built-in governors that are standard for all RACINE pumps.



OPERATING ECONOMIES — *The Colored area in the graph below shows the horsepower lost during one holding cycle of a simple press circuit using a constant volume pump. The black area shows the horsepower consumed when a Racine "Variable Volume" Pump and Pressure Booster is used to do the same work.*



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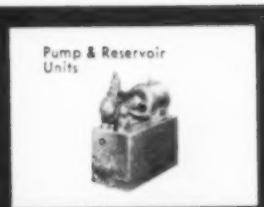

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the empire of which it was the the capital has disappeared. Its decline began at the peak of its prosperity. Wealth had softened the individuals both physically and morally. Abuses in the distribution of the ever increasing public charity funds sapped the nation of its vitality. Candidates for re-election to political office squandered public funds to buy votes and thus assure victory at the polls. The work and sacrifices involved in raising a family in the face of ever increasing taxations, the desire for easy living, plus indolence and love of luxuries caused childness to become general among the upper classes.

Of course such things couldn't possibly happen in the U. S. A. And he who dares to predict it would be scorned and laughed at. A favorite trick is to read a passage predicting the downfall of the nation and then point out with smug satisfaction that the passage had been written hundreds of years ago. The Romans invented that one. And of course in Rome also, any citizen who dared predict the fall of the Empire would have been laughed at. In fact, the Roman Empire did not fall. It slowly disintegrated and vanished off the earth, just dried up and blew away, one might say.

The pages of modern history tell the story of the disintegration of Spain, of the decline of France to a third rate power and the gradual shrinking of the British Empire. In every instance the causes were the same: excessive wealth; easy living, squandering of public funds; lowering of moral standards; graft; corruption; waste and dishonesty in government. Is it logical to believe that the same combination of facts and circumstances will not bring the same results? The nation needs an aristocracy of brains and intelligence which will steer it back to the faith of our fathers.

Initiative

It is amazing how many people will fail to do what they really want to do until they are driven to it. In a highway accident a large four-door sedan was knocked over on its side. It blocked all traffic. A man was at the wheel, two middle aged ladies in the back seat. A crowd of gaping spectators from the stalled cars quickly gathered. The three people in the car struggled vainly to get out. No one did a thing to help them until a young man came along and quickly taking in the whole situation, shouted, "Come on everybody, let's help the people to get out." A dozen or so men stepped forward with enthusiasm. They immediately righted the car, rolled it to the side of the road, used newspapers

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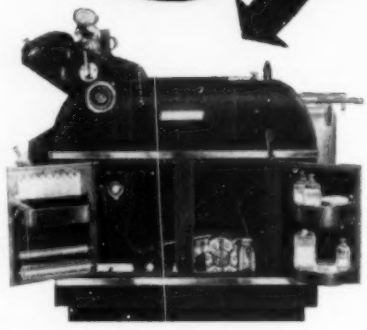

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2. One of the many Denison high-pressure high-volume pumps for either constant or variable volume delivery. Volume control by stem, handwheel, or pressure compensation. Capacities: 2 to 35 gpm. Simplified axial-piston design — rugged, dependable, highly compact.

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The DENISON Engineering Co., 1157 Dublin Rd., Columbus 16, Ohio

DENISON
Pumps and Controls

Sans Souci.....continued

to brush all the glass off the road and soon traffic was rolling as usual. The young man who had initiated the job directed all the efforts but did nothing other than that. He was the executive.

What about it? Lots. In an average crowd only one man out of twenty has the personality and initiative to be a genuine self starting leader. Many people will do a job with enthusiasm but not until they have a leader to start them going. Most people find it more comfortable to do nothing. It is not that they are inconsiderate or lazy. The gaping crowd at the automobile accident was probably waiting for a cop to come along. It just didn't occur to them to do the obvious thing so that they could clear the road and continue on their way. But as soon as the leader stepped forward they all got to work.

In business we have comparable situations almost daily. Traditional methods and techniques hang on and on because no leader steps forth to challenge them. Man after man follows the meandering paths of his predecessors. Many of them are lacking in initiative. Some of them lack the courage or incentive. Many fear ridicule. Of course only the leaders, the men with initiative, the men who are not afraid to tackle new ways of doing things, get ahead and become the executives.

Incentive Management

Right along the same line we have the question of incentive. About a week ago I received a book, "Incentive Management" written by James F. Lincoln, president of Lincoln Electric Company. The price is one dollar, post paid. The first half dozen chapters of the book are about incentive and the important part it plays in our daily lives. Most people know it but few have figured it out the way Jim Lincoln presents it in this book. Mr. Lincoln rates incentive as the most important element in any activity.

Most people have the idea that the most important incentive is money. In many instances money rates pretty far down the line. In fact, if money were the only incentive there wouldn't be much urge for doing anything. Recognition, the desire for praise, pride of accomplishment, applause, and many more elements are incentives. Usually the total incentive is a combination of such urging forces. Money may or may not be the most important.

Be sure to get your copy of this splendid little book. —G.F.N.

It is impossible in a column like this to really do justice to the book that Mr. Lincoln has written.

OUR READERS SAY

Photo Credit Omitted

To the Editor:

The November, 1951 issue of PRODUCT ENGINEERING carries an article on pages 143 through 145 about Plastic Molding Presses. One of the main illustrations at the top of page 144 shows a cutaway drawing of a Watson-Stillman press.

This drawing was made for the Socony-Vacuum Oil Co., Inc. at a cost of approximately $2,000. It ran in a Socony-Vacuum ad in *Business Week* and other McGraw-Hill publications.

While Socony-Vacuum is happy that PRODUCT ENGINEERING was able to use it, the company feels that it should have been given some kind of credit reference. —JOHN H. OWEN
New York, N. Y.

Ed—You may be sure that, if PRODUCT ENGINEERING had had any idea that this was a Socony-Vacuum picture, it would have been glad to give that company a credit line. As things stand, we will be glad to call attention to the fact that the illustration belongs to Socony-Vacuum Oil Company.

A special section titled ERRATA in which we acknowledge errors of this kind appears at the end of the Our Readers Say column.

Either Way Its Packing Standards

To the Editor:

We have in preparation a catalog of Leather and Synthetic Packings (Cups, Flanges, U's, V's, Oil Seals, O-Rings, etc.) for International Packings Corporation, affiliated with Graton & Knight Company, Worcester, Massachusetts. In this connection, we are preparing material covering various standard specifications such as

JIC—Joint Industry Conference
ASTM—American Society for Testing Materials
AMS—A special committee of ASTM
AN—Army and Navy
MIL—Military
KKL—Federal
. . . doubtless there are others.

It occurs to us that you may have covered this entire subject or parts of

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DENISON HydrOILics

Pumps and Controls

Shown on Opposite Page are Typical Examples

Applying the full advantages of oil-hydraulic equipment to new requirements that play a major part in today's fast-moving industrial progress, has been the work of a continuous research and development program at Denison for many years.

As a result, press equipment has been reduced in bulk and complexity . . . its speed and efficiency have been increased for all types of production jobs . . . and newly developed all-automatic control features slash costs even on short run production jobs. Pumps of improved design, with full emphasis on efficiency at high pressures, are now a reality. Greater accuracy has been incorporated into pressure controls for all types of circuit needs up to 5000 psi. Tooling designs and methods that reduce scrap losses, boost production rates and improve the quality of work are now in wide, daily use because of procedures developed at Denison.

Recently, special research in applying high-pressure hydraulics to new and bigger commercial and defense-production needs has brought remarkable gains in many phases of industry.

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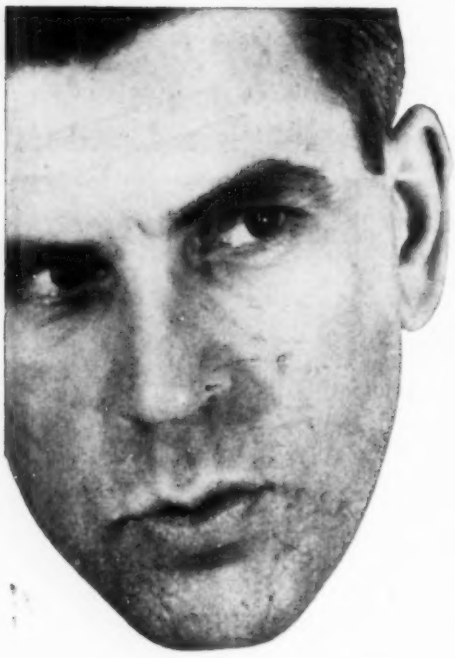

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precision bearings

it in some recent articles or at least would be in a position to tell us where we might get additional information. We think it would be very helpful to give a brief outline of the make-up and purpose of each group so that both customer and salesman would have a better understanding of what the symbols stand for. It is always surprising how little real information people have about these things.

The company, of course, is getting their information together also, but we naturally turn to you for up-to-date and authoritative information along these lines. —H. F. KING, V. P.
Wm. B. Remington, Inc.

Ed—We did carry an article on the JIC hydraulic standards in February, 1949. We also carried last year in January, an article titled "Designing for Military Requirements." This listed and discussed the problems of military standards as well as federal specifications. It did not, however, go into detail on any of these specifications.

For detailed information on military specifications, you should contact Les Neville, Director of Public Relations for the Joint Armed Services, Pentagon Building, or any of the agencies that are listed in the article on designing for military requirements. The director of the Frankfort Arsenal could probably give you as quick a rundown on these specifications as you could get from Washington.

For federal specifications and standards, contact Hugh Odishaw, Assistant Director of Specifications, National Bureau of Standards, Washington, D. C. For details on JIC standards, write to Ralph A. Richardson, Head of Technical Data Section, General Motors Corp. Development Laboratories, Detroit, Michigan. Of course the standards of any one of these groups are very involved. The problem with all of them except for the ASTM is to facilitate purchasing of acceptable equipment. The ASTM has as its goal the establishment of standardized testing procedures so that test data on a material obtained in one company can be correlated and compared directly with data that might be secured by another investigator.

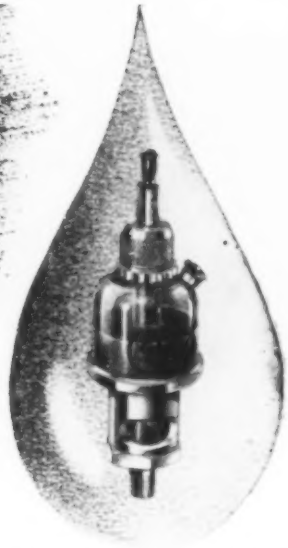
Draftsman's Delight

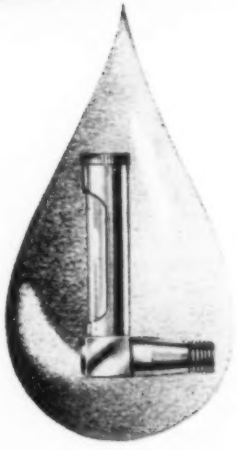
To the Editor:

An article entitled, "Drawing Details and Notations That Must Be Checked," Table 1, intrigued our drafting supervisors to the extent that they all desire copies.

Therefore, we herewith ask your

For Lubricating Devices Call On GITS First!





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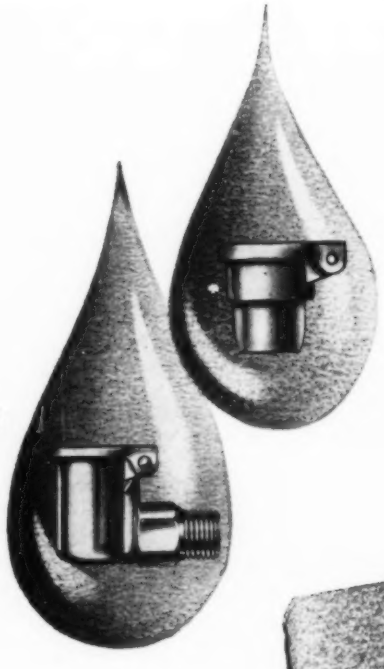

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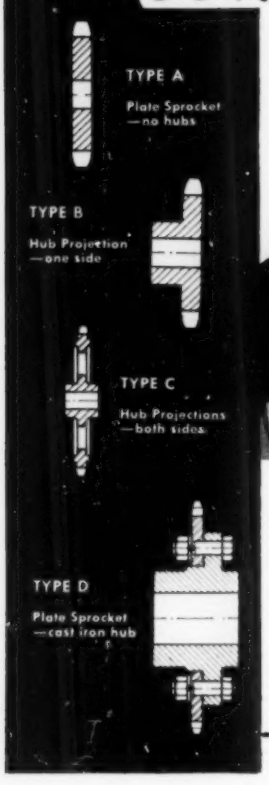

If your product calls for any of these roller chain sprockets as diagramed, the new Sewall Stock Sprocket Catalog can save you time and money. *May we send you a copy?*

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for Every Plant Use

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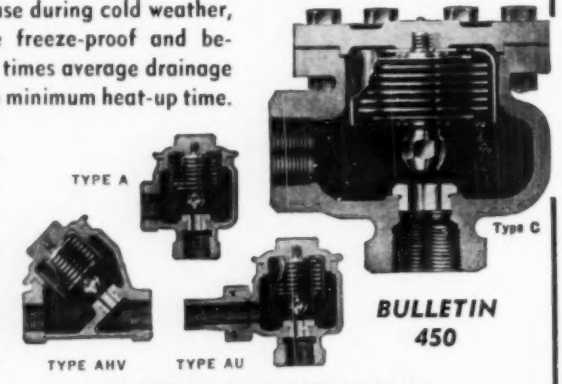

BULLETIN 450

200 OREGON ST., WILKES-BARRE, PA.

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

permission to reproduce Table 1 and circulate it among our drafting personnel.

—WALTER M. SALE
General Electric Co.

Ed—We are very glad to extend to you permission to copy the table in the Rowbotham article, "Engineering Checkers Promote Economical Production," that was published in the July 1951 issue of PRODUCT ENGINEERING.

This was Table 1, "Drawing Details and Notations That Must Be Checked."

Ceramics Acknowledged

To the Editor:

Your article on "How to Tackle Materials Substitution" in your October issue, completely omits technical ceramics.

There is no shortage in technical ceramics. Design engineers as a group have relatively little knowledge of where and how to use technical ceramics.

In recent years, the better ceramic makers have learned to economically manufacture technical ceramics to close dimensional tolerances where the contour lends itself to grinding.

For hardness, heat resistance and total and permanent rigidity, technical ceramics usually offer superior performance at lower costs.

Technical ceramics are coming into increased use as reference plates, wear plates, thread guides, extrusion nozzles for pencil leads, battery carbons.

Air-acid jet inserts, welding nozzles, burner tips, precision jigs or templetes for heat treating or induction heating operations are common applications of technical ceramics. These of course in addition to the wide use of technical ceramics as insulators in electrical appliances, radar, radio, television.

In general the weakness of technical ceramics from a design standpoint is their inability to withstand mechanical shock. But where mechanical shock is not a requirement, technical ceramics offer superior resistance to thermal or electrical shock. They are not affected at room temperature by alkalis or acids except corrosive fluorine compounds.

If you would like technical information on technical ceramics I would suggest that you contact Mr. Hans Thurnauer, Vice-President, Research, American Lava Corporation, Chattanooga 5, Tennessee.

—GEORGE W. POWER
Chattanooga, Tennessee

Ed—Many thanks for your note regarding our omission of technical ce-

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SPECIAL APPLICATION
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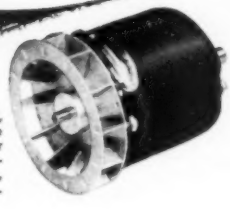
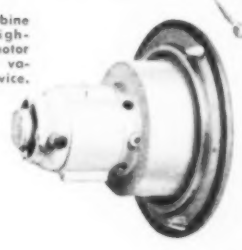
Proved DEPENDABILITY

Series motor suitable for many intermittent duty applications where space and weight are important considerations.

Completely enclosed motor with ball bearings insures operating continuity in pump and similar applications.

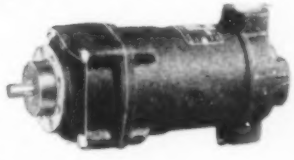


Compactly designed, capacitator-type induction motor for wire recorders, electronic tube cooling, and similar services.

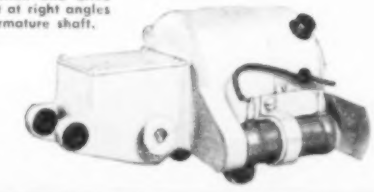


Heavy-duty turbine driven by a high-speed universal motor for commercial vacuum cleaner service.

Planetary inbuilt speed reducer permits a straight-line drive, symmetrical construction; insures good performance.



Series universal motor with inbuilt gear reduction and drive shaft at right angles to armature shaft.



• Successful operation in many thousand motor-driven products and devices — over a period of 36 years — has proved the thorough reliability of Lamb Electric Motors.

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O-M is *all* Cylinder—packing more *power* per square inch than any other type! No tie rods or bulky end caps, saves ⅓ in installation space. In full range of sizes from 1½" to 8" bores. All machined steel with bearing bronze. Parts and mounting brackets fully interchangeable. Special design standard parts applicable to almost all "custom" installations.

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ramics from our October section "How to Tackle Materials Substitution." In a section of this sort, where space is limited as it was with us, the best we can do is to try to select the materials that we discuss on the basis of their importance to the majority of our readers.

I think you will find that with the exception of plastics, most of that section was concerned with metals. However, we have not by any means ignored the subject of technical ceramics. Perhaps you may have seen the two-part article done for us by Mr. Michaelson of Sylvania Electric on technical refractory ceramics in our July and August 1951 issues. American Lava Corporation provided several of the photographs for this article, a great many of which we again had to leave out because of space limitations.

From Tokyo; Subject: Torque Converter

To the Editor:

One of our customers brought the following requirements to us regarding Torque Converters for Diesel and Gasoline Engines.

We, therefore, should like to ask you the following questions to which kindly send us your prompt reply.

1. Names and addresses of the makers in the U. S.
2. What is the principle of the operation of the common converter?
3. Are the converters manufactured under the patent of Ungstorong?
4. Do the automobile makers such as Ford, General Motors, etc., manufacture the converters by themselves? If not, from what makers are they purchasing the converters? Do they manufacture them on their own design or under the patent of Ungstorong?

Your information for the above will be highly appreciated by us.

—H. KASHIYAMA
Kyokuto Boeki Kaisha, Ltd.
Tokyo, Japan

Ed—Here is a reprint of an article published in March 1950 issue of PRODUCT ENGINEERING on fluid power transmissions, the second part of which deals exclusively with torque converters and fluid couplings. From our November 1951 issue we are sending you a copy of an article by Mr. Gibson of Twin Disc Clutch Company on matching torque converters to driven loads. Both of these articles should give you the background of operation and method of application you want.

Principal manufacturers in this

TRANSFER MOLDING PHENOLIC TO STEEL

A Typical example of Shaw Solutions To New Production Problems.

Newly designed ignition system booster coil case, for International Harvester Co. Asbestos-filled phenolic is transfer molded to the steel cans to insure a pressure tight seal. An entirely new process resulting in greater efficiency without appreciable increased cost!

Another example of Shaw's design, development and production facilities . . . available to solve your plastic problems.

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POPE qualifies as your Spindle Department.

YOU name the type or size Spindle and specify POPE.

You get finer finishes and continuous, peak production of accurate parts.

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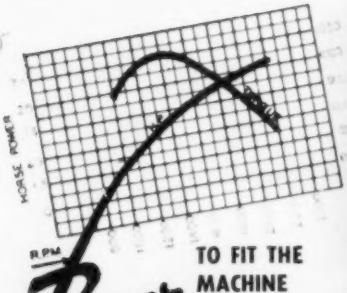

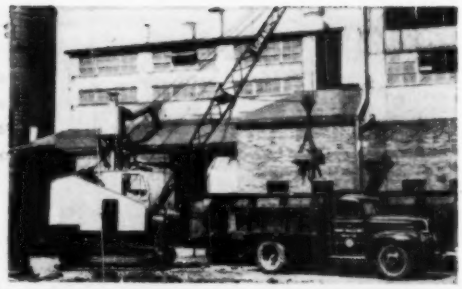

TO FIT THE MACHINE AND THE JOB

Power

WISCONSIN-POWERED

Power Plants, Inc. Generator

Three carloads of scrap travel fast from freight cars to trucks every day with this crane on the job. It's equipped with a 36" ECM magnet, and the generator, built by Power Plants, Inc., Cleveland, Ohio, is powered by a Wisconsin Air-Cooled Engine.

Over and above time and labor saved through Wisconsin Engine dependability, servicing and maintenance are reduced to a minimum. For example, bearing failure is unheard of due to tapered roller bearings at both ends of crankshaft. Fool-proof air-cooling means no winter freeze-ups or summer overheating. And an easily-serviced OUTSIDE magneto with impulse coupling delivers all-weather quick starts. These features, combined with rugged construction, are the basis for the most dependable, most versatile power in the 3 to 30 hp. range . . . WISCONSIN POWER.

Write for details covering 4-cycle single-cylinder, 2-cylinder and V-type 4-cylinder models.

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World's Largest Builders of Heavy-Duty Air-Cooled Engines

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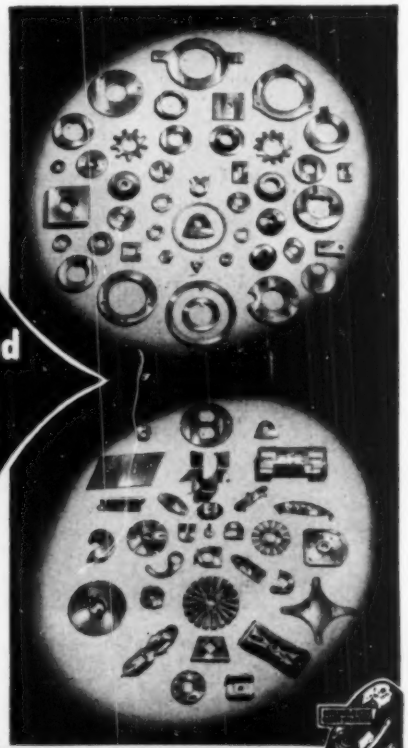

Standard and Special Washers, of every description, from every kind of material, any desired finish . . . designed for every purpose . . . utilizing more than 22,000 Sets of Dies.

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country include the following concerns:

1. Allison Div., General Motors Corp., Indianapolis, Indiana
2. Buick Div., General Motors Corp., Flint, Michigan
3. Borg-Warner Corp., Chicago, Illinois
4. Twin Disc Clutch Company, Rockford, Illinois
5. Speiser Division, Dana Corp., Toledo, Ohio.

The patent situation on torque converters is at present up in the air. The original units manufactured in this country were under British license, but we understand that these patents have run out and no attempt has been made to repatent the principle of the device. There are some patents that apply specifically to certain types of equipment, as for example, the three-stage converter being manufactured by Twin Disc Clutch Company.

Some automobile concerns do make their own units. Ford buys torque converters for Mercury and Ford from Borg-Warner, as does Studebaker. Buick and Chevrolet get their units from the Detroit Transmission Division of General Motors. In the automotive industry, perhaps the Allison Division of General Motors has done more to applying torque converters to vehicles than any other division of a motor car manufacturer.

Where Can I Get It?

No Names Please

To the Editor:

The June issue of OEM News published by PRODUCT ENGINEERING indicates that PRODUCT ENGINEERING reaches approximately 270 consulting engineers. We know it is not a usual practice to release such a list of names but we have so many accounts in the electrical industrial field that we are wondering what steps could be taken to reach the consulting engineers mentioned.

We would actually like to have a list of these engineers, however, if this is absolutely unavailable, can we reach these men through direct mail?

—MARION E. STALK
Hugh H. Graham & Associates, Inc.

Ed—On a number of past occasions, this same question has been raised. Several technical difficulties stand in the way of developing a mailing list of the type in which you are inter-

ested. Past efforts to do it have resulted in angry consultants and wrangled customers. In view of this fact, we feel such a list could not be developed at this time.

Rubber-Metal Weld Info

To the Editor:

We note that your "Our Readers' Say" department provides information on suppliers of products and instruments.

We should like information on the product or process which has the trade name "Cycleweld". This is a method of bonding rubber to metal.

Can you tell us where we could get the necessary material, or must we send the parts concerned to another plant for processing. —DOUGLAS G. NOILES
Economic Machinery Co.

Ed—The "Cycleweld" process was developed by the Chrysler Corporation. Full details about this process and the necessary material and information about technique can be obtained by addressing the Cycleweld Division, Chrysler Corporation, Detroit.

Cement Mixer With Boom

To the Editor:

On page 114 second column top, in the May 1951 issue of PRODUCT ENGINEERING magazine, there is an article referring to concrete mixers that carry a portable power hoist or movable boom to deliver the cement across excavations or higher elevations.

I would like to get more information about this machine. Can you tell me who makes it. —A. PERLICK
Brooklyn, N. Y.

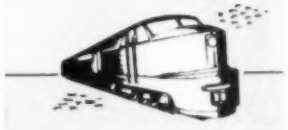
Ed—The leading manufacturer of this type of equipment is Mixermobile Manufacturers, Box 7527, Portland 20, Oregon.

Another manufacturer who makes a ½ yard mixer with a movable boom which can deposit concrete as high as 25 ft above the ground is the Koehring Co., Milwaukee 16, Wisconsin.

ERRATA

Nov., 1951 Page 144. *Preplasticizer Triples Capacity of Molding Press.* The credit line under the cutaway drawing of the Watson-Stillman press was inadvertently omitted. This illustration was supplied through the courtesy of the Socony-Vacuum Oil Company.

GEARS *by Fairfield*



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At Fairfield, your gears are in the hands of specialists equipped with every modern facility for producing fine gears efficiently and economically. *For the Best in Gears, Specify Fairfield!*

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spell real economy!

What is the best way to attach a certain contact material to contact arms of another material for use in certain equipment under certain conditions?

Stackpole not only has the answers, but likewise offers full facilities for handling this important operation in production quantities by the most suitable methods. This PLUS service to users of Stackpole contacts is a big factor in saving them money by eliminating scrap and in assuring maximum dependability for their products.

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Helpful Contact Data

Far more than a listing of Stackpole contact types, Catalog 12 contains a wealth of helpful data on contact materials and their applications. Write for yours today.

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All contact shapes and sizes in SILVER GRAPHITE • SILVER LEAD OXIDE SILVER NICKEL • SILVER MOLYBDENUM • SILVER TUNGSTEN • COPPER GRAPHITE • PRECIOUS METALS . . . *and many other materials*

NEW BOOKS

Descriptive Geometry

HAROLD BARTLETT HOWE, *Head of the Department of Engineering Drawing, Rensselaer Polytechnic Institute. 332 pages, 6 x 9 in. Published by the Ronald Press Co., 15 E. 26th St., New York 10, N. Y.* $4.

In this textbook the direct-method approach is used instead of the earlier plane-trace method. This procedure is used in effort to make the theory of the subject more interesting and enable the student to master the content more readily. To effect the attainment of proficiency in teaching the subject, this book uses a great many pictorial sketches. This method is used to stimulate the student's capacity to perceive and to visualize, and make him express his space conceptions in picture form.

Complexities in space picture sketching are introduced in steps that progress from simple fundamentals to more complicated combinations.

Many practical engineering problems are presented for study and explanation. As basic visualization training in structure and machine design, special emphasis is here placed on vectors, and particularly on their use in finding stresses in planar and noncoplanar structures and for the representation of moments. A portion of the text is devoted to an explanation of the principles of perspective drawing by means of picture sketches.

Alternating-Current Circuits

K. Y. TANG, *Professor of Electrical Engineering, The Ohio State University. 603 pages, 6 x 9 in. Published by International Textbook Co., Scranton, Pa.* $6.

Progressive work in both the fields of power and of communication demands a more thorough grasp of the physical principles and laws of electric circuits. For this reason, the author has devoted much space to the study of the effects of the circuit elements on the flow of current in an electric circuit. The relations of instantaneous values are also emphasized throughout the book.

The chapter on Network Theorems includes the Superposition Theorem, Thevenin's Theorem, the Maximum Power Transfer Theorem and the Y-Delta Transformation. Chapter 10, Voltage and Current Loci, is an intro-

duction to circle diagram work in alternating-current machinery. Professor Tang's approach in the study of Symmetrical Components is a sympathetic one. The treatment of direct-current and alternating-current transients has been much simplified by the inclusion of Chapter 18, Differential Equations. The common practice of using single-subscript notation for simple circuits, and the double-subscript notation for polyphase circuits, and the single-subscript with arrows in meshes denoting positive sense in communication networks has been followed throughout the various chapters. In this book the material has been so presented that the various chapters, made as independent of one another as possible, can be selected at will in suiting the particular needs of the individual.

External Pipe Threads

24 pages, 8½ x 11 in. Published by Reed Rolled Thread Die Co., Worcester, Mass. Paper cover, $0.75.

The information in this pamphlet applies only to external taper and straight pipe threads. It contains data in condensed and simplified form computed and compiled from various standards. It is arranged for the convenience of those who use the thread rolling process.

Included are tables of dimensions, formulas, definitions and tolerances for taper pipe threads and straight pipe threads.

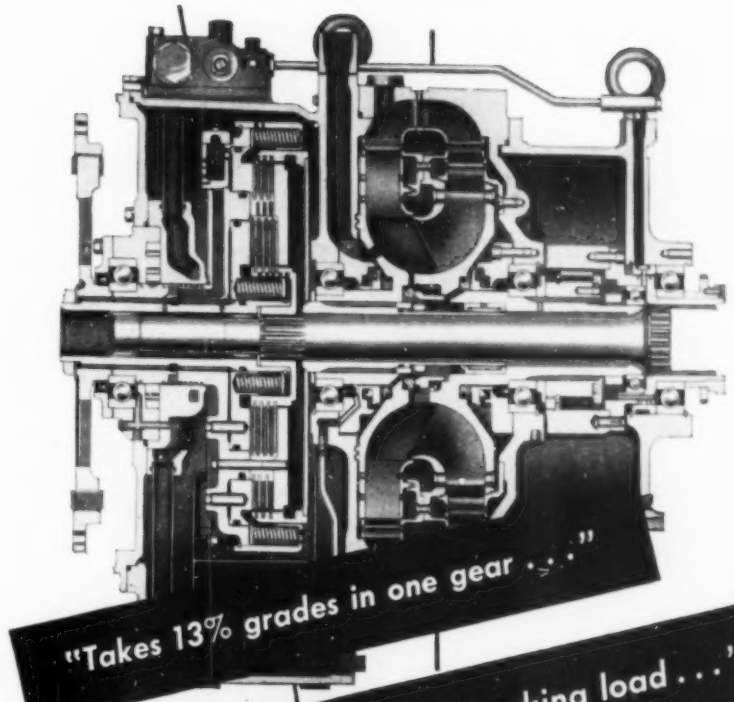
The Grinding Wheel

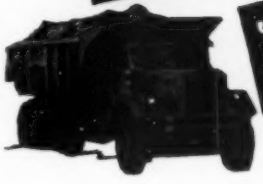
KENNETH B. LEWIS. *407 pages, 6 x 9 in. Published by the Grinding Wheel Institute, Greendale, Mass.* $3.50.

This book was prepared to serve as a comprehensive text on the subject of grinding wheels and grinding operations. Written in easy-to-understand language, the book is directed to students and apprentices, men and women in the grinding industry, and executives in industries related to the grinding industry.

The first few chapters are devoted to the materials, methods and processes employed in the manufacture of abrasive wheels. This is followed by a complete description of the kinds, shapes and sizes of wheels currently available. The remaining twenty-three chapters are devoted to the application of these wheels.

There are complete chapters on such subjects as: grinding fluids, rough grinding, cylindrical grinding, centerless grinding, surface grinding, thread





Model DF

Twin Disc Hydraulic Torque Converter

"Field reports of the Twin Disc Three-Stage Hydraulic Torque Converter with Direct Drive feature, in big heavy-duty trucks, are proving that 99% of forward gear shifting can be eliminated in off-highway operation. Extensive tests on the Mesabi Iron Range in this Twin Disc equipped Dart truck indicate that these converters can significantly reduce time on hauling cycles on this, probably the world's toughest trucking, with loads up to 30 tons and grades up to 13%. Furthermore, very *substantial* savings on axles, tires, gears and brakes are reported."

That is the first paragraph from a just-published four-page bulletin on the *new* Twin Disc Model DF Three-Stage Hydraulic Torque Converter.

You'll want the complete story because never before have so extensive tests been reported on three-stage hydraulic torque converters with an *in-built* braking feature which no other torque converter can claim. Write today, and be sure to ask specifically for Bulletin No. 162. It may show you how to save thousands of dollars in truck operation.

TWIN DISC
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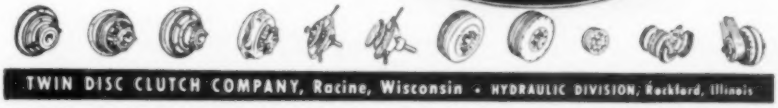

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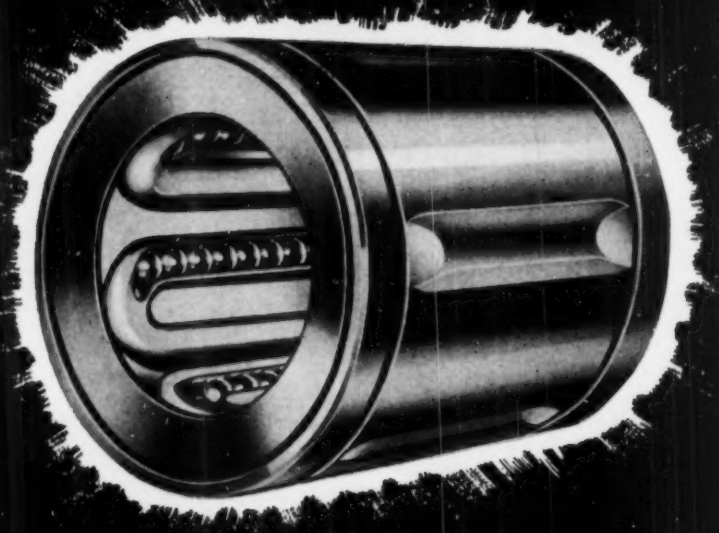

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grinding, gear grinding, disk grinding, internal grinding, grinding non-metallics, and grinding cemented carbides.

The other chapters cover: truing, dressing and balancing; tool and cutter sharpening; honing, lapping, and superfinishing. The final chapter considers cost factors of grinding operations.

The appendix features a 16-page chart of grinding wheel recommendations based on the type of work or operation being performed. There is also a complete description of the causes and corrections of common grinding errors.

Patents For Technical Personnel

DR. WORTH WADE, *registered patent attorney and chemist, Pres. of American section of the Societe de Chimie Industrielle; 44 pages; 6 x 9; heavy paper-cover. Published by Chemonomics Inc. 400 Madison Ave., New York, N. Y.;* $3.00.

Without footnotes, case histories, and legal technology, the book simply and accurately discusses what a patent is, lists the steps which must be taken to protect an invention, and discusses the interference and prosecution of patents.

This handbook has been written for the inventor and employee of a chemical process plant, using the language of the layman, and not the patent attorney.

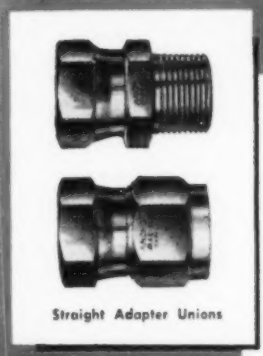
The book describes a typical patent department of a company, and discusses its relation to the inventor-employee. It also tells how patent rights help you and your company, what inventions are assignable to your company, and how patents benefit the industry.

An important, and so far a neglected subject, is covered in the last chapter: How to read a patent. Not only does this section analyze the contents of a patent, but it presents a systematic method for analyzing and checking claims, finding and avoiding infringement, and gives a check list for protecting your patent rights. A four page pictorial section shows an invention from the idea to the patent.

Photoelastic Stress Analysis

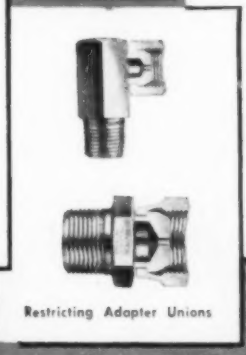
16 pages, 5¾ x 8½ in. Published by Eastman Kodak Co., Rochester 4, N. Y. $0.35.

To incorporate recent developments, a revised edition of this publication is now available. Like its predecessor, the new booklet begins with a few gen-

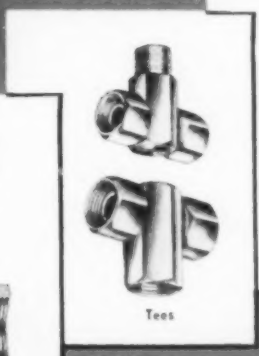


Straight Adapter Unions

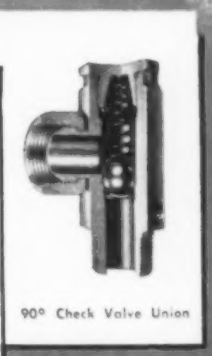
45° and 90° Adapter Unions



Restricting Adapter Unions



Tees



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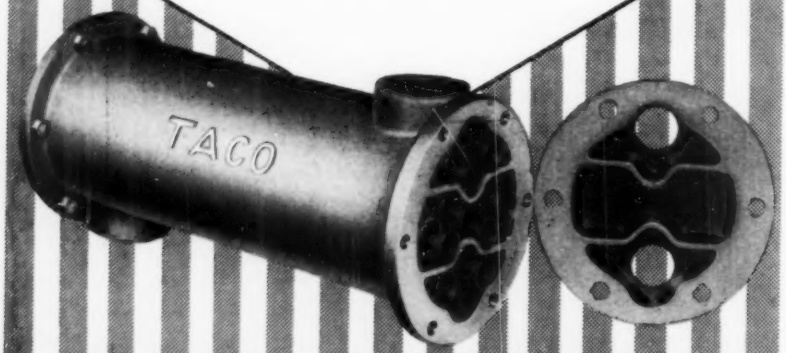

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eral remarks about the importance of photoelastic stress analysis. It discusses briefly other methods of stress analysis and then launches into a discussion of the principles of photoelasticity. This section covers polarized light, double refraction or birefringence, isochromatic lines, isoclinic lines, circular polarization, and stress patterns. Photoelastic light sources, filters, polarizers, analyzers, quarterwave plates and condensers, are then described.

Materials suitable for making models of the part to be tested are discussed and the actual making of the models is considered. Models for three dimensional stress analysis and photographic materials for use in the process are also covered.

Finally, there is a bibliography of books and articles on the subject. This should prove of considerable value to workers in the field.

ASTM Standards on Petroleum Products and Lubricants (With Related Information)

Prepared by ASTM Committee D-2 on petroleum products and lubricants. 784 pages, 6 x 9 in. Published by American Society for Testing Materials, 1916 Race St. Philadelphia 3, Pa. Heavy paper cover, $5.75; cloth cover, $6.40.

This 1951 compilation of ASTM Standards on Petroleum Products and Lubricants (with related information) brings together in compact, readily usable form most of the ASTM standards, test methods, and specifications widely used in this field. The tests for knock rating of engine fuels and certain standards for measuring and sampling petroleum are not included in this compilation.

This edition gives in their latest form 129 ASTM standards, including 116 test methods; 7 specifications; 1 classification; 3 lists of definitions relating to petroleum, specific gravity, and rheological properties of matter; 2 tentative recommended practices for the purchase of uninhibited mineral oil for use in transformers and in oil circuit breakers, and for designating significant places in specified limiting values; and other material.

Widely used standards in this compilation cover the following broad classifications of petroleum products: crude petroleum, butadiene, motor and aviation fuels, petroleum solvents and naphthas, diesel fuels, distillate burner fuels, kerosene and illuminating oils, lubricating oils, turbine oils, electrical insulating oils, plant spray oils,

petroleum sulfonates, greases, petrolatums and paraffine waxes. Included also are standard specifications for ASTM thermometers, and test method and standardization of etched-stem liquid-in-glass thermometers.

New material includes tentative test methods for: total inhibitor content (p - tertiary - butylcatechol) of butadiene; bromine number of petroleum distillates by color indicator and electrometric methods; reduced pressure distillation of petroleum products; and hydrocarbon waxes used for electrical insulation.

Appendices include proposed methods of test for: penetration of lubricating greases worked more than 60 strokes; measurement of density and specific gravity of liquids to the fifth place by the Bingham pycnometer; saponification number of petroleum products by the para-xylenol blue color-indicator method; oil content of petroleum waxes; kinematic viscosity; and two proposed methods of determining motor and research octane numbers of small samples. There are also recommendations on the form of ASTM methods of test for petroleum products and lubricants.

Advanced Engineering Mathematics

C. R. WYLIE, JR., *Professor and Chairman, Dept. of Mathematics and Astronomy, Univ. of Utah. 640 pages, 6½ x 9¼ in. Published by McGraw-Hill Book Co., 330 W. 42 St., New York 36, N. Y. $7.50.*

This comprehensive and well organized book covers ordinary and partial differential equations, Fourier series and the Fourier integral, operational calculus developed through the use of the Laplace transform, Bessel functions, theory of functions of a complex variable, vector analysis and such techniques of advanced numerical computations as the numerical solution of equations and systems of equations, finite differences, harmonic analysis, least squares, and the method of Stodola.

After three introductory chapters dealing with ordinary linear differential equations, there is a long chapter devoted to their applications to mechanical and electrical circuits. The material is sufficiently complete to enable the student to solve many important practical vibration problems, both electrical and mechanical. In addition there is a skillful treatment of equivalent circuits and the construction of electromechanical analogies.

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form contains some recent original work on the determination in finite form of the inverses of periodic-type transforms. The work on functions of the complex variable is followed by a chapter devoted to the application of this theory to the classical potential flow of incompressible fluids.

Emphasis is placed on the relationship of each topic to other topics in the book and to the general problems of the engineer. Several hundred completely worked problems are included which range from simple illustrations to involved examples of the application of theory. In addition there are over 1,000 problems for student solution, carefully graded in difficulty.

An extensive appendix covers many important topics from the borderline areas between college algebra and the theory of equations, and calculus and advanced calculus.

A Basic Training Manual On Statistical Quality Control

RUDOLPH FREEDMAN AND JOSEPH MOVSHIN. *78 pages, 8¼ x 10¾ in. Published by The St. Louis Society for Quality Control, 6651 Kingsbury, St. Louis 5, Mo.* $2.50.

This manual has been written for use in short elementary courses in statistical quality control. It may be used for plant training and short courses that are often given by technical societies. It may also be used as a laboratory manual in conjunction with a standard text on quality control in a full course.

The manual consists of a brief text which is included to serve as a set of notes for the students. The heart of the manual is a series of work sheets covering frequency distributions, X & R Charts, p charts, pn charts, c charts and sampling. The manual has been written around the principle that "we learn by doing" and the work sheets give the student an opportunity to perform exercises and to make the necessary calculations so that he will be able to put quality control into practice.

Heat and Thermodynamics

MARK W. ZEMANSKY, *Professor of Physics, The City College of New York. 465 pages, 6 x 9 in. Published by McGraw-Hill Book Co., 330 W. 42 St., New York 36, N. Y.* $6.

The purpose of this third revision is, as before, to provide an introduction to the subject matter of heat and thermodynamics for students preparing for a career in theoretical physics, theo-

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These diagrams show a few of the ways in which Sylphon bellows assemblies are used—where there's a design problem involving control of temperatures or pressures. They open and close valves, dampers, etc., absorb expansion, provide packless construction, have many more uses.

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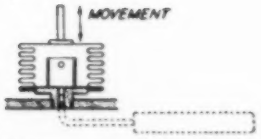

Fig. 1 Thermostatic Motor—This type of assembly is widely used in temperature regulators, etc., where a thermostatic charge is confined in the bellows and where a valve, switch, damper, etc. is to be operated in response to temperature changes.

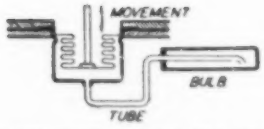

Fig. 2 Thermostatic Motor—This assembly is used where it is desirable to have the thermostatic charge confined outside the bellows and within a cup. May be used with or without remote bulb shown.

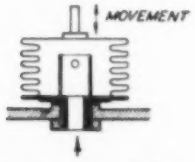

Fig. 3 Pressure Motor—Bellows assemblies are often employed to convert pressure effects into controlled movement. Fig. 3 shows such an assembly where the pressure is applied inside the bellows.

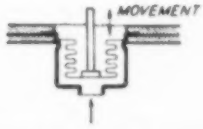

Fig. 4 Pressure Motor—This assembly differs from Fig. 3 in that the pressure is applied outside the bellows and within a cup.

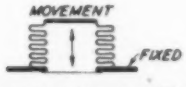

Fig. 5 Expansion Chamber—This type of assembly is employed to absorb thermal or pressure expansion. With suitable heads, it would be used to serve as a reservoir for a liquid or gas. Example: Oil reservoir for electrical cable joint.

Fig. 6 Expansion Joint—Packless and leakless construction for expansion joints used to absorb thermal expansion of pipe lines carrying steam, water, etc. May be used to absorb vibration and provide flexible connection for other applications.

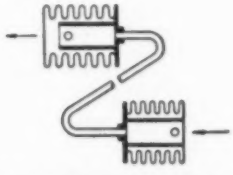

Fig. 7 Motion Transmission—Two bellows assemblies joined by a tube for hydraulic transmission of motion or power. Motive force applied may be either thermostatic or mechanical.

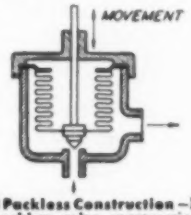

Fig. 8 Packless Construction—Illustrating packless valve construction. Same principle used to seal stem movement or adjustment in many types of apparatus.

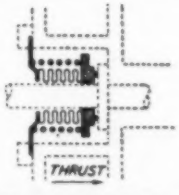

Fig. 9 Shaft Seal—Widely used for refrigeration compressors to prevent leakage around revolving shaft. Spring pressure holds nose of seal against shoulder on shaft. Another type used rotates with shaft and seals against stationary plate.

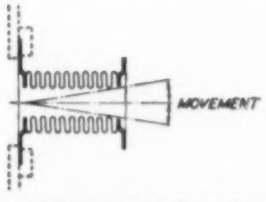

Fig. 10 Flexible Joint—Providing a means to seal a flexible joint or mechanical movement of levers, linkage, etc., against leakage where the movement must be conveyed outside an enclosure. Example: Operating stem of float switches, etc.

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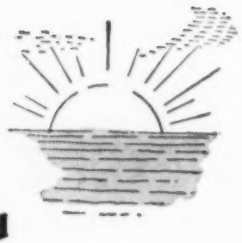

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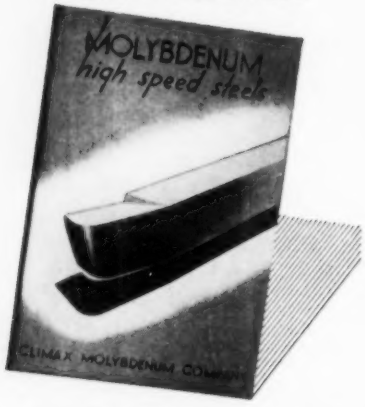

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retical chemistry, or engineering. The first ten chapters treat the fundamentals of the subject, including the concepts of temperature, heat, internal energy and entropy, and the first and second laws of thermodynamics. The remaining nine chapters deal with physical, chemical, and a few engineering applications.

In the new edition, the theory and measurement of the mechanical equivalent of heat and heat capacity have been incorporated within the chapter on the first law of thermodynamics. The remainder of the chapter on heat has been expanded and transformed into a chapter on the transfer of heat. Various phenomena in low temperature physics which formerly appeared in separate chapters have been combined to form the basis of a new and extensive chapter on the physics of very low temperatures.

The chapter on heat transfer has been extended to include streamline flow and Poiseuille's law, Reynolds number and turbulence, natural and forced convection, and the theory of the single-current heat exchanger.

Many other changes, in addition to new figures and new problems, serve to make the present revision one of the most up-to-date and comprehensive treatments of the basic theory of thermodynamics.

Corrosion Guide

ERICH RABALD, *Director and Chief-Chemist of the C. F. Boehringer & Sohne (Germany), 629 pages, 6½ x 10 in. Published by the Elsevier Pub. Co. Inc., 402 Lovett Blvd., Houston 6, Texas.* $12.50.

Though the literature of Europe and America is rich in good books on corrosion, the author feels that this book is justified in that it approaches the problem in a different manner from the normal texts on corrosion. The *Guide* has arisen from problems which are met by the engineer who is actively practicing. To him the question of corrosion and the choice of material is often a difficult and costly problem, which may prevent him from constructing a plant or from keeping it in operation. Corrosion and its causes interest him mainly to the extent that he wishes to avoid it. A practical engineer will be ready to use experience gained elsewhere, and it is in fact often difficult to persuade him to use new materials. Therefore, in this *Guide* the old tried methods are catalogued with their advantages and dificiencies. In addition, however, the tabular arrangement of performance

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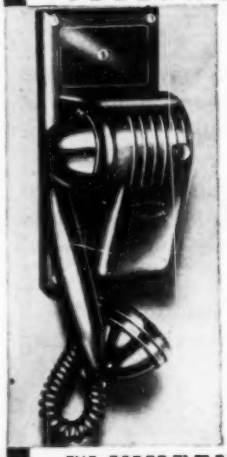

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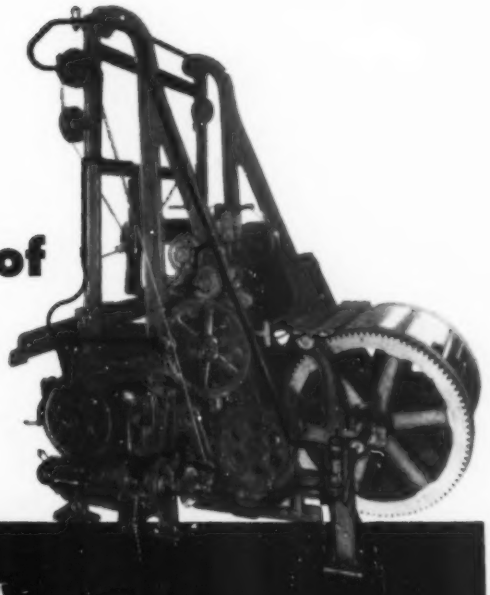
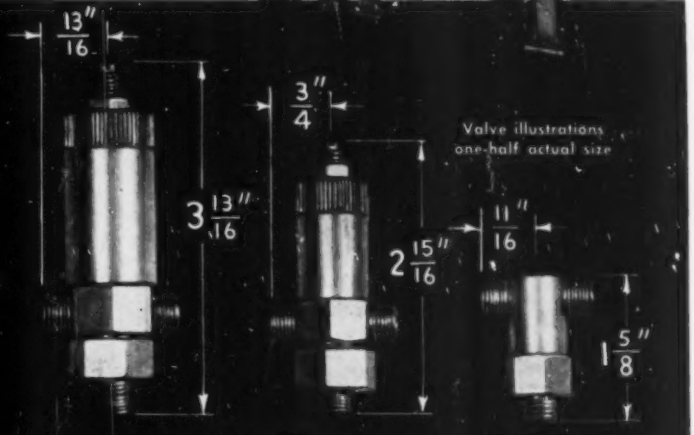


ALEMITE Accumeter SYSTEM



Virtually any machine that must be lubricated with fluid oils or light greases can have the protection of automatic *mechanized* lubrication. Alemite's Type I Accumeter System is the answer! So simple, so compact is this versatile *single line* system, that you can incorporate it in your designs with remarkable ease.

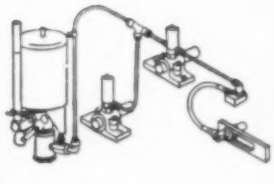
The Alemite Type I Accumeter Automatic Lubrication System consists of a lubricant pump, a distribution system of tubing, and *force-feed* valves mounted on or near individual bearings.

From one central point, it safely, surely lubricates all the bearings on a machine . . . automatically . . . while production goes on. Increases output by eliminating shutdown for lubrication! Ends the risk of lubrication errors or neglect by your customers! Reduces maintenance and repair costs, prolongs machine's life.

Alemite Accumeter Systems meter lubricants with a sustained accuracy unmatched by any other method. In fact, tests show *no variation* in the amount of lubricant discharged to bearings . . . even after 73,312 lubrication cycles—equivalent to 122 years of twice-a-day service!

What's more, Alemite Accumeter Automatic Lubrication is not merely "one-shot" lubrication. It is *continuous* between cycles. That's because Alemite's exclusive "accumulating" feature *prolongs* the discharge of lubricant to bearings.

Alemite Accumeter Automatic Lubrication is adaptable to machines of every type and size. There are three separate systems, to cover your full range of needs. Write now for Form 22-189, a free 16 page brochure giving full data. And for specific application recommendations, include description of machines you are presently working on. Alemite, Dept. T-12, 1850 Diversey Parkway, Chicago 14, Illinois.



This *Single Line* System Serves Any Type Bearings

Alemite's Type I Accumeter System can meter oil or grease to rotary, oscillating, stationary — plain or anti-friction bearings. Serves up to 400 bearings. Valves for any bearing capacity. FIXED or ADJUSTABLE output.

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of materials in use gives the user an opportunity of finding out easily about other materials that have so far scarcely been used or have not been used at all. These may offer some special advantages for particular problems.

In the first section, some general considerations are given on the selection of materials. This is followed by a short introduction to the general aspects of corrosion, a knowledge of which leads to better use of data given later. The bibliography at the end of the book indicates the most important books and journals for those particularly interested. The tables in which over 250 corrosive and more than 40 materials of construction are set out are similar to the Dechema tables of materials that have appeared in Germany, but they are not all identical.

Industrial Furnaces—Vol. I

W. TRINKS, *Associated Engineers, Professor Emeritus of Mechanical Engineering, Carnegie Institute of Technology. 526 pages, 6 x 9½ in. Published by John Wiley & Sons, Inc., 440 Fourth Ave., New York 16, N. Y. $10.*

Since its initial publication in 1923, Industrial Furnaces has been a thorough exposition of all phases and problems of practical technology. This book lays down and discusses the basic principles underlying all furnace design and operation, provides numerous graphic illustrations and typical examples which reinforce the text, and offers conclusions—rather than untried theories—which have been tested and proved in actual furnace practice.

The fourth edition of Volume I brings this treatise completely up-to-date by incorporating the most recent scientific facts which research has discovered about heat transfer and furnace design as well as present day design and operating principles and techniques. The arrangement of the subject matter remains much the same as the third edition with the exception that infrequently used material has been moved to the appendix; the volume is divided into sections on the capacity, economy, thermal efficiency, strength and durability, and movement of gases in furnaces. About 40 percent of the text has been rewritten and 94 new illustrations have been added. The tables have been brought up-to-date and many of the statements have been clarified. All calculations and tables have been changed from gross tons to net tons.

The revisions mentioned above com-

bine to make this edition even more useful to those designers and users of industrial furnaces who want to know how to get the best value out of the fuel they use and how to apply it most effectively.

Business and Professional Speech

LIONEL CROCKER, *Professor of Speech, Denison University;* 470 *pages,* 6 x 9 *in. Published by the Ronald Press Co., New York, N. Y.;* $4.

Written to offer information and advice not only on the platform speech and normal business situations, this book also touches upon such related material as the problems faced by the program chairman of civic and other organizations. The author gives a study of relationships of speaker, speech, audience, and the fundamentals of the speech situation. The importance of human motives and their use by the speaker, at the same time emphasizing the need for high ethical standards, are also explained.

The book is divided into two parts. The first is devoted to the Theory of Speech, which covers such points as: How to look at your audience; what the audience hears; how to get and hold attention; audience analysis; promoting acceptance of yourself and your ideas; putting the speech together; language used; and others.

The second part is called Common Types of Business and Professional Speeches. This covers: the sales talk; the policy speech; the good will speech; the oral report; the interview; radio and television; and other types of speeches.

The book is illustrated with selections and complete speeches by leaders in public life.

The Algebra of Vectors and Matrices

THOMAS L. WADE, *Florida State University.* 189 *pages,* 5½ x 8½ *in. Published by Addison-Wesley Press, Inc., Cambridge* 42, *Mass.* $4.50

This book is intended to give an elementary expository presentation of matrix algebra. It is concerned largely with an elementary exposition of the algebra of vectors and matrices. This exposition is articulated with the basic concepts of modern algebra in the broad sense, that is, group, integral domain, field, ring, basis, dimension, and isomorphism.

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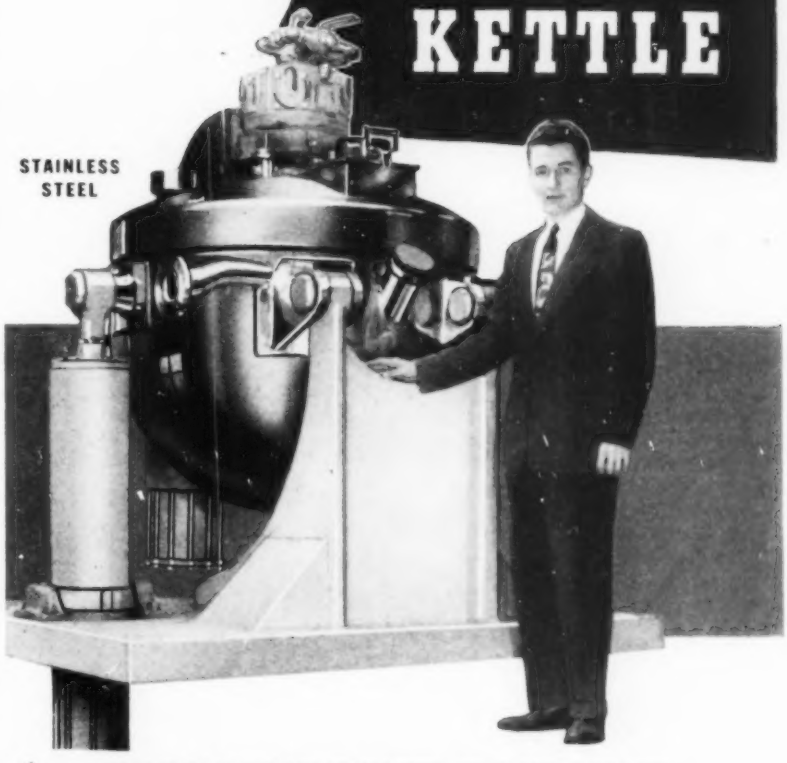

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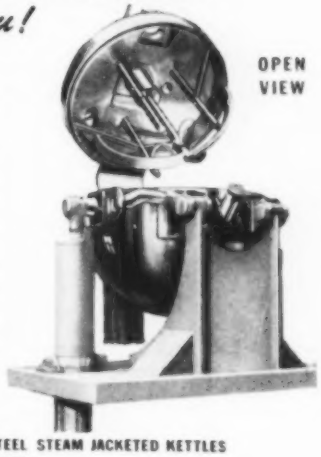

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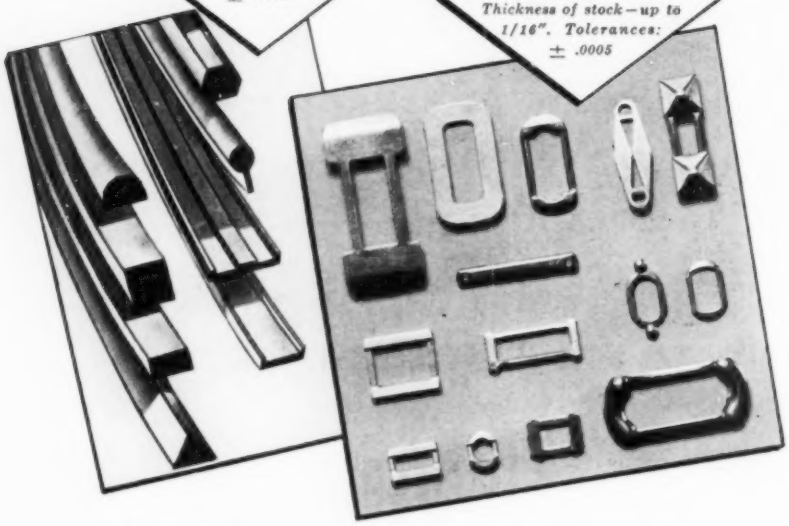

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be primarily learning about vectors and matrices, he will be getting that knowledge in the setting of modern algebraic theory. This book, therefore, is suitable for use in the first course of a sequence of courses devoted to modern algebraic theories.

The physicist, engineer, theoretical chemist, statistician, or psychometrician will find here in a single source, in relatively simple, readable language, the essential features of matrix algebra that for him constitutes a powerful and widely used tool.

Considerable use is made of the summation notation, the index symbolism, and transformations, all of which are common in tensor theory. This book, therefore, may well serve as a prerequisite for work in matrix and tensor calculus.

The mathematical background of the student using this book is assumed to be a first course in analytic geometry and an acquaintanceship with the usual theorems on determinations as given in a standard college algebra book.

Engineering Statics and Dynamic

DAN H. PLETTA, *Head of Applied Mechanics, Virginia Polytechnic Institute.* 400 *pages,* $9\frac{3}{8}$ x $6\frac{1}{2}$ *in. Published by Ronald Press Co., 15 E. 26th St., New York* 10, N. Y. $5.50.

The problem of preparing textbooks is a never never-ending one. There are always newer and different and improved methods of presentation. With over twenty years of varied teaching experience, Prof. Pletta has attempted to present his ideas in a manner that the student can grasp and understand. He endeavors to emphasize a few fundamental concepts with which the beginner can apply to an infinite variety of situations. Since the student is in a formative frame of mind, the way in which he is taught to approach a problem is most important. As a result of his training, the student may have a bagful of formulas or develop an intuitive ability to apply fundamental concepts to new designs.

The material covers the usual subject matter of a beginning course. Its arrangement follows the deductive approach. In the chapter on Internal Resistance of Solid Bodies, it is a departure for a course in statics for it introduces the subject of Strength of Materials. There are two chapters on the laws of motion: one discusses the equations of kinetics and the other describes the inertia force method. On the subject of relative motion, there is a new treatment which obviates the

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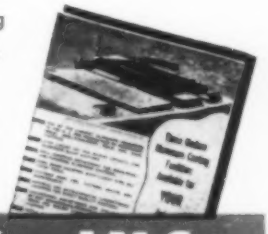

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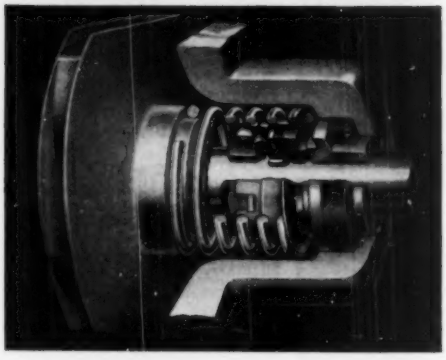

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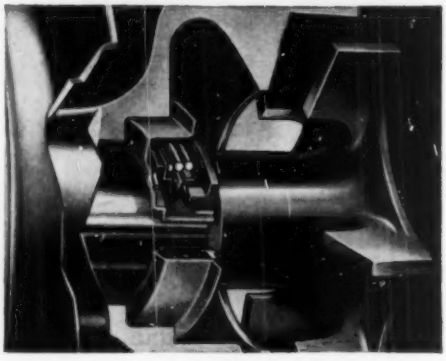

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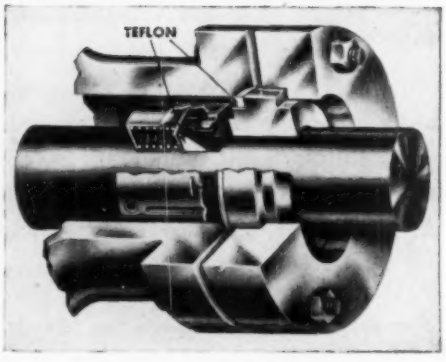

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use of Coriolis' Law. Following each section, there are a number of carefully chosen problems to illustrate the fundamental principles.

Following a chapter on Vibrations, there is a final chapter on Dimensional Stability and Model Similarity. Both of these should prove helpful to the undergraduate as introductory material.

Heating Design and Practice

ROBERT HENDERSON EMERICK, *Consulting Mechanical Engineer, 453 pages, 6½ x 9½ in., Published by McGraw-Hill Pub., Co., 330 W. 42 St., N. Y 36, N. Y.*, $8.00.

This book has been prepared with two ends in view. First, it is intended to present to all persons concerned with heating the basic theories of heating design with demonstrations of how these theories are worked out, followed in many instances by case histories and evaluations of results taken from practical experience.

These examples and evaluations are of importance because they point out how interdependent design and practice actually are. Admittedly a knowledge of design principles makes for better practice, but equally pertinent is a recognition of practice's capacity, on occasion or under special conditions, to show bluntly the need for a qualification of theory.

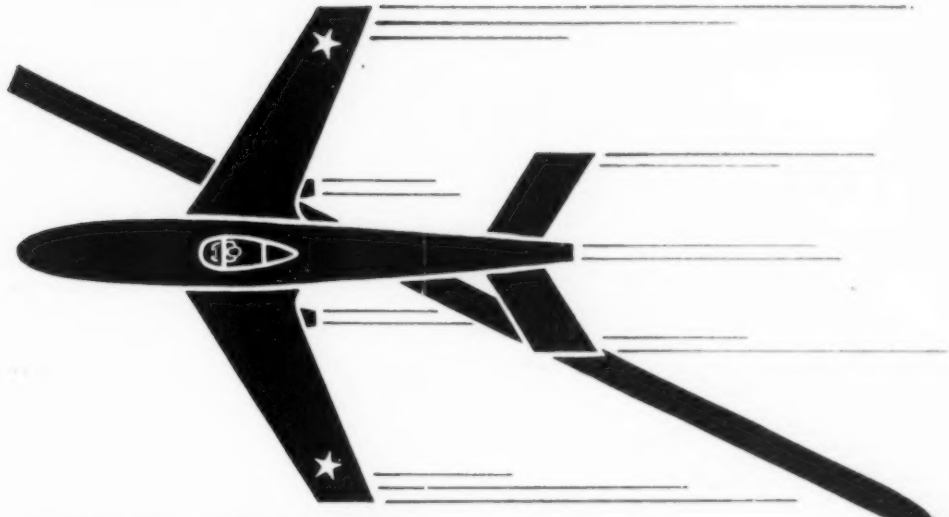
For its second purpose, this book attempts to bring together working information on subjects and problems closely allied to heating which, sooner or later, are likely to demand the responsible attention of the heating engineer. In this category are those chapters that examine in detail the combustion of various fuels; the design of fuel handling and storage systems, including piping for gas and oil; the characteristics of industrial refractories and insulation; the preparation of specifications and the analysis of bids.

Many of these data have been harvested from scattered sources, or directly from experience, and in consequence have not always been on hand in time. Those concerned with the heating field should therefore find these chapters most useful.

Television Servicing

WALTER H. BUCHSBAUM. *340 pages, 6 x 9 in. Published by Prentice-Hall, Inc. 70 Fifth Ave., New York, N. Y.* $5.35.

In Part one, the author explains the theory of operation of every section in



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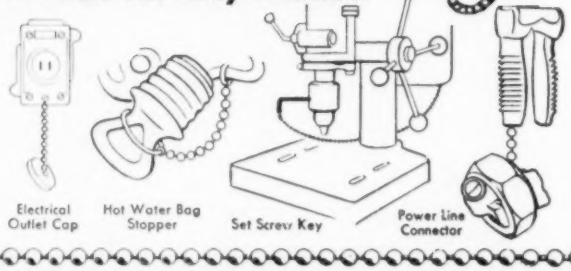

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the modern TV receiver. Theoretical discussion is held to a minimum, with practical examples, illustrations, and comparisons used abundantly. A knowledge of higher mathematics is not needed for a complete understanding of the material in this, and the other two parts. To further clarify these data the author includes an easy-to-comprehend outline of the entire television system.

Alignment and installation of the television receiver is shown in detail in Part two of Television Servicing. Step-by-step procedures are given, covering such aspects as sound channel alignment, video IF alignment, and aligning RF amplifiers, mixers, and oscillators.

Part three is a complete guide for trouble-shooting the TV receiver. The author lists all of the possible defects, and shows how they appear outside of the receiver . . . facilitating the prompt spotting of the trouble and its source by eye and ear. Classified for ready reference, each defects is thoroughly analyzed to show what steps must be taken to correct it. The author describes the causes and cures for defective deflection, poor sound and picture quality, poor cathode ray tube performance, as well as the loss of synchronization.

Quality-Control Handbook

J. M. JURAN, *B.S. in E.E., J. D., Consulting Management Engineer; Adjunct Professor of Management Engineering, New York University; Formerly, Chief of Inspection Control Division, Western Electric Co.* 6 x 9 *in.*, 800 *pages. Published by McGraw-Hill Book Co., Inc.*, 330 *W. 42nd St., New York* 18, *N. Y.* $10.

Here is the story of quality control, presented in thorough, comprehensive handbook form. For authoritative answers to questions on any phase of planning or carrying out a quality-control program; for basic or advanced review of all phases, not only the statistical, of the quality-control function; for quick reference to many formulas, data, record forms, and other practical information, this detailed manual can be used.

The handbook has been planned to develop: 1) Those principles which are universal, no matter what the product or process. The first nine sections are devoted to this, with appropriate examples and cases. 2) Applications of principles to particular products or processes. Six sections are devoted to such applications.

The fifteen sections cover the eco-

nomics of quality control; how to organize for quality; acceptance, control, and assurance of quality; and similar aspects; but also application to specific processes and products, such as chemical, textile, and aircraft.

The book is the work of several specialists; illustrative examples from actual cases and records are profuse, so that the book brings the reader the broadest sort of perspective on the quality function, and practical working information based entirely on what is being done with quality control in industry today.

Materials Technology For Electron Tubes

WALTER H. KOHL, *Consultant to the Director of Research, Collins Radio Company.* 493 *pages,* 6 x 9 *in. Published by Reinhold Publishing Corp.,* 330 *W.* 42*nd St., New York, N. Y.* $10.

This book presents up-to-date information on materials used in the construction of electron tubes. It is the first one in English which aims at a thorough scientific treatment of the main solids which enter into the construction of electron tubes.

The treatment of materials such as Glass, Ceramics, Mica, Tungsten, Molybdenum, Tantalum, Copper, Nickel, Graphite is one feature of the book. Each chapter dealing with these metals contains an extensive tabulation of the physical characteristics and the chemical reactions taking place with various reagents. The description of processes used for the application of these materials is another feature. Included is a critical review of the work done throughout the world by many research workers. Certain data and description of processes are published here for the first time. There is a review of atomic theory and the classification of crystals which provides a welcome introduction to the novice in this field. The tube engineer, development engineer, experimental physicist, chemist, materials engineer and technician, in any field where these materials are being used, can get from the book the pertinent data required and, from the references, a quick guide to more extensive study of the literature. Although the title of this book is specific about the field of application, namely, electron tubes, a materials engineer in any field can benefit from the data given. Many of the properties of molybdenum, for example, of interest to the electronics man may solve other problems.

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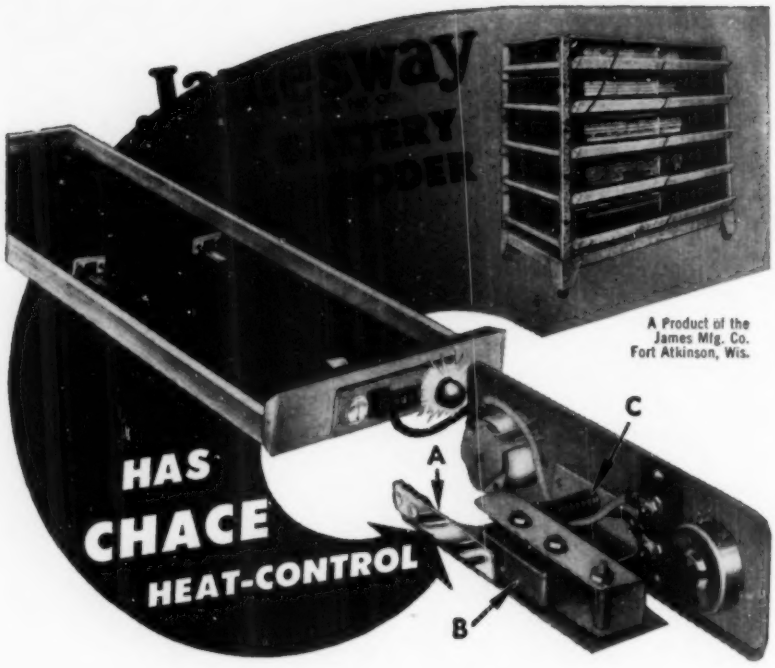

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The James Mfg. Co. fabricates its element from Chace #2400 strip. Chace offers 29 types of thermostatic bimetal in strip, random coils and complete elements fabricated and assembled from customers' prints. We also offer the consultation of our highly expert Applications Engineers who will assist you in the development of your own temperature actuated device. Write for your copy of our 64-page guide to the selection and designing of thermostatic bimetal elements.

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RCA Produces Rugged Xenon-Filled Rectifier

A XENON-FILLED, half-wave rectifier tube, designed to meet military requirements for a rectifier capable of performing efficiently under extreme ambient temperatures, has been designed by the RCA Tube Department.

The rugged tube is engineered to maintain its high efficiency under ambient temperatures ranging from 75 degrees below zero to 90 degrees above zero centigrade. Because of its content of xenon gas, it will function under severe atmospheric heat and cold that would make a mercury-vapor type of rectified tube inoperative. Furthermore, its rugged construction permits use under conditions of severe vibration.

It is rated at either a peak inverse anode voltage of 10,000 volts and an average anode current of 0.25 ampere, or a peak inverse anode voltage of 5,000 volts and an average anode current of 0.5 ampere. It has a low voltage drop which is virtually constant at approximately 10 volts.

Two tubes, when employed in single-phase, full-wave service with the peak inverse anode voltage limited to 5,000 volts, will deliver to the filter a d-c output current of one ampere at 1,600 volts. When the peak inverse anode voltage is 10,000 volts, the two tubes will deliver a d-c output current of 0.5 ampere at 3,200 volts.

Utilizing a medium-shell, small 4-pin base with bayonet, the rectifier takes the standard four-contact socket. The latter should be equipped with filament contacts capable of withstanding 5 amperes continuously without over-heating.

Air Force and Navy Agree On New Synthetic Lubricant

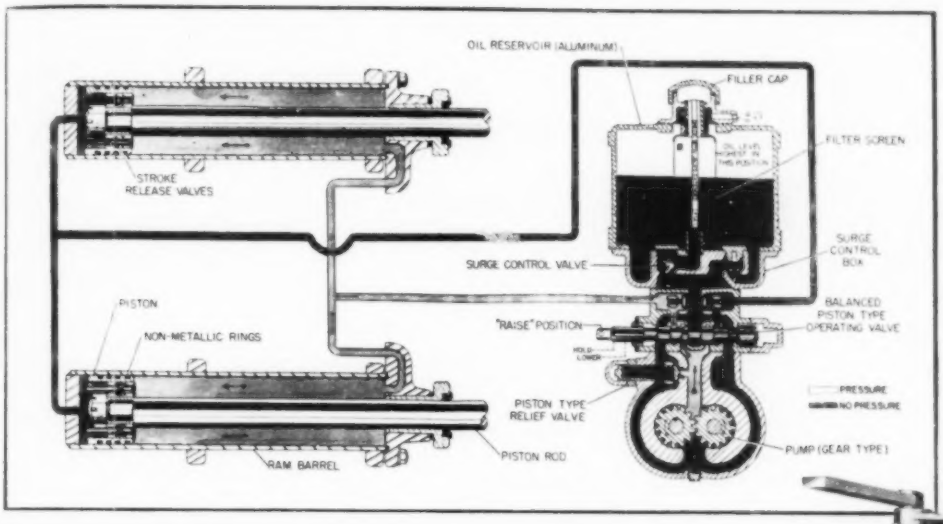
WASHINGTON—Research staffs of a half dozen chemical firms and several petroleum companies have combined their efforts with the Navy and the Air Force to produce the first joint military specification for a synthetic lubricating oil for gas turbine aircraft engines.

Initial research for the new synthetic lubricant was started in 1940 and was done at the Naval Research Laboratory in Washington. Testing was done by the two services and industry.

The base of the new lubricant is one of a class of chemicals known as aliphatic diesters. Phenothiazine is added to prevent oxidation at high temperatures, and tricresyl phosphate to prevent gear wear.

The new oil will withstand operat-

FOR THAT "Something Extra" IN PERFORMANCE



SPEED

POWER

VERSATILITY

SIMPLICITY

TROUBLE-FREE OPERATION

THE FAMOUS LPC FLUID POWER CONTROL

Pump, valve and oil reservoir are all combined into a single compact unit that mounts on the front of the tractor behind the radiator guard. This new "closed system" design completely eliminates long suction lines, reduces the hazard of leaks and assures greatly increased speed and efficiency. In addition, the entire unit is skillfully engineered and precision built for utmost simplicity, easy servicing, and long, trouble-free operation.

DESIGN YOUR PRODUCT WITH LaPLANT-CHOATE HYDRAULIC UNITS

FOR designers and manufacturers of products that can be improved by hydraulic operation, LaPlant-Choate Hydraulic Units give the performance "extras" which bring extra advantages into your competitive sales picture.

These powerful, smooth-operating units . . . jacks, pumps, valves or the compact, all-in-one fluid power control . . . supply the speed, flexibility, and instant response to controls that keep equipment operating economically and efficiently.

That's why so many manufacturers like the ones listed below are using LaPlant-Choate Hydraulic Systems for the utmost in full hydraulic operation. For complete details, send for Bulletin B-1152B, or write your requirements to LaPLANT-CHOATE MANUFACTURING CO., INC., Cedar Rapids, Iowa.

A few of the well-known manufacturers who make good products even better with LPC Hydraulic Units

Service Supply Corp.
(Manufacturing Division)
THE LODOVER

•

The Warner & Swasey Co.
GRADALL

Pacific Car & Foundry Co.
CARCO HYDRADOZERS

•

Wm. Bros Boiler & Mfg. Co.
BROS BULLDOZERS

Municipal Supply Co.
THE GUTTER SNIPE

•

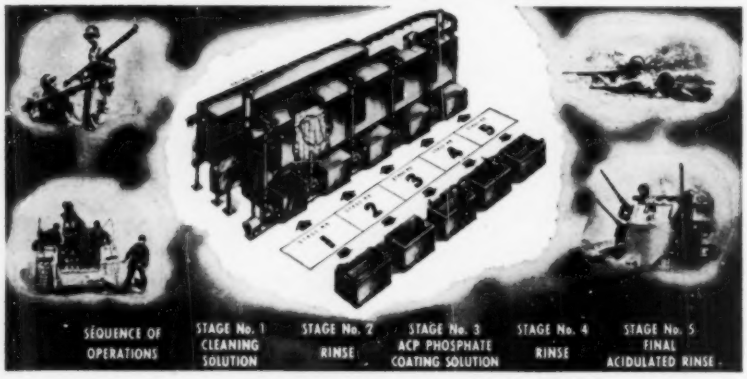
Pittman Manufacturing Co.
THE HYDRALIFT

LaPLANT CHOATE

AMERICAN CHEMICAL PAINT COMPANY

AMBLER CHEMICALS ACP PROCESSES PENNA.

Technical Service Data Sheet
Subject: METAL PRESERVATION AND PAINT PROTECTION WITH ACP PHOSPHATE COATING CHEMICALS


SEQUENCE OF OPERATIONS
STAGE No. 1 CLEANING SOLUTION
STAGE No. 2 RINSE
STAGE No. 3 ACP PHOSPHATE COATING SOLUTION
STAGE No. 4 RINSE
STAGE No. 5 FINAL ACIDULATED RINSE

U.S. ARMY PHOTOGRAPHS COURTESY OF "ORDNANCE MAGAZINE"

Typical spray and dip phosphating equipment and some ordnance products that are now given a protective phosphate coating for extra durability under all kinds of severe exposure conditions. Both military and civilian applications of ACP phosphate coating chemicals are shown in the chart below.

SELECTION CHART OF ACP PROTECTIVE COATING CHEMICALS FOR STEEL, ZINC, AND ALUMINUM

METAL	ACP CHEMICAL	OBJECT OF COATING	TYPICAL METAL PRODUCTS TREATED	GOVERNMENT SPECIFICATIONS
STEEL	"GRANODINE" Zinc Phosphate Coating Chemical	Improved paint adhesion	Steel, iron, or zinc fabricated units or components, automobile bodies, refrigerators, washing machines, cabinets, etc., projectiles, rockets, bombs, rifles, small arms, belt links, cartridge tanks, vehicular sheet metal, tank bolts and links, recoilless guns, etc.	MIL-S-5002 JAN-C-490, Grade 1 JAN-F-495 U.S.A. 57-0-2, Type II, Class C U.S.A. 51-70-1, Finish 22.02, Class C U.S.A. 50-60-1 16 E4 (Ships)
	"PERMADINE" Zinc Phosphate Coating Chemical	Rust and corrosion prevention	Nuts, bolts, screws, hardware items, tools, guns, cartridge clips, fire control instruments, metallic belt links, steel aircraft parts, certain steel projectiles and many other components.	MIL-C-16232 U.S.A. 57-0-2, Type II, Class B U.S.A. 51-70-1, Finish 22.02, Class B Navy Aeronautical M-364 U.S.A. 72-53 (See An-F-20)
	"THERMOIL-GRANODINE" Manganese-iron Phosphate Coating	Wear-resistance anti-galling, safe break-in of friction or rubbing parts. Rust proofing.	Friction surfaces such as pistons, piston rings, gears, cylinder liners, camshafts, tappets, crankshafts, rocker arms, etc. Small arms, weapon components. Hardware items, etc.	MIL-C-16232 U.S.A. 57-0-2, Type II, Class A U.S.A. 51-70-1, Finish 22.02 Class A Navy Aeronautical M-364 U.S.A. 72-53 (See AN-F-20)
	"GRANODRAW" Zinc-iron Phosphate Coating	Improved drawing, extrusion, and cold forming	Blanks and shells for cold forming, heavy stampings, tube; tubing for forming or drawing; wire, rod; etc.	———
ALUMINUM	"ALODINE" Protective Coating	Improved paint adhesion and corrosion resistance	Aluminum products of similar design such as refrigerator parts, wall tile, signs, washing machine tubs, etc; aircraft and aircraft parts; bazookas (rocket launchers), helmets, belt buckles, clothes dryers, clothesline, rocket motors, etc., aluminum strip or sheet stock.	MIL-C-5541 (See also QPL-5541-1) MIL-S-5002 AN-F-20 U.S. Navord O.S. 675 16 E4 (Ships) AN-C-170 (See MIL-C-5541) U.S.A. 72-53 (See AN-F-20)
ZINC	"LITHOFORM" Zinc Phosphate Coating Chemical	Improved paint adhesion	Zinc alloy die castings; zinc or cadmium plated sheet or components; hot dip galvanized stock; galvanneal; signs; siding; roofing; galvanized truck bodies; etc.	QQ-P-416 RR-C-82 JAN-F-495 AN-F-20 U.S.N. Appendix 6 U.S.A. 72-53 (See AN-F-20)

CHEMICALS ACP PROCESSES

WRITE FOR DESCRIPTIVE FOLDERS ON THE ABOVE CHEMICALS AND FOR INFORMATION ON YOUR OWN METAL PROTECTION PROBLEMS

CHEMICALS ACP PROCESSES

ing temperatures from minus 65 to plus 500 degrees F and will not boil off at high temperatures. Contemplated production figures are classified.

Along with this development work, Naval Research Laboratory chemists considered the problem of a supply of chemicals for synthetic lubricants. A common source of the acids needed for synthesizing diesters in the early 1940's was castor oil, an imported product. In studying other sources, consideration was given both to materials which would be available in quantity from domestic sources and would not interfere with the production of other needed materials.

A total of 34 diester fluids were developed from a variety of basic materials, including petroleum sources, corn products, oats, stockyard fats, and coal tar. From a careful study of the properties of these fluids, a smaller group was selected for further development into lubricants of immediate interest.

Hot Windshield Clears Pilots' View

ELECTRICALLY HEATED SELF-DEICING WINDSHIELDS that also eliminate interior fogging have been developed for Super Constellation transports by Lockheed. The new windshields boast an automatic temperature control for adjustment in relation to outside air.

To prevent both exterior ice and interior "fogging," the new windshield utilizes a layer of stannous oxide Nesa (nonelectrostatic formulation A), only 45 millionths of an inch thick, as a heating element.

The conductive Nesa is sprayed on the back of a $\frac{3}{16}$ inch pane of glass, while it is almost red hot. This glass later becomes one of three layers of the laminated windshield. Other sections are a $\frac{3}{8}$ inch pane, next to the pilot, and a $\frac{1}{4}$ inch center layer of elastic vinyl, termed the "fireman's net" because it is designed with both stretch and strength, to protect pilots from birds that might fly into the windshield.

To prevent fogging, the back of the windshield is kept approximately 50 degrees warmer than the front, which in turn is maintained about 50 degrees warmer than outside air. At the same time, the temperature of the vinyl birdproof layer stays between 80 and 120 degrees, the range at which it has best conditions of strength and stretch.

Automatic temperature control was achieved by incorporating in the vinyl a thermistor sensing element, a semiconductor composed of rare earth oxides. This thermistor feels temperature changes and "tells" a control circuit when to turn on or shut off power.